Rural Subsistence and Protected Areas: Community Use of the *miombo* woodlands of Lake Malawi National Park

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Thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

University College London
University of London

February 1996

Abstract

This study examines the utilisation of *miombo* woodland by fishing communities in Lake Malawi National Park (LMNP). Combining methodologies from the natural and social sciences, patterns of use of non-timber forest products (NTFPs), and the impact of harvesting practices on the resource base, are described. The main focus is the commercial and subsistence use of primary woodland resources including: fuelwood, construction materials and grass thatch.

Aerial photographic analysis and a quadrat based vegetation survey are used to examine the impact of local utilisation practices on the *miombo* woodland. Multivariate analyses assess the importance of different environmental variables in explaining the floristic composition of the woodland vegetation.

A range of NTFPs are used locally but market surveys indicate that few products are traded outside the villages. A marketing analysis suggests that urban trade is constrained by the low economic value of woodland resources compared to the high cost of rural transport. Specific patterns of collection and use are apparent for each resource. This thesis explores the impact of different harvesting practices on the *miombo* woodlands. Using household surveys and time allocation, the effects of children on patterns of wood collection and use are examined. The role of daughters in fuelwood collection is discussed in relation to theories of fertility and family size. Furthermore, behavioural ecology approaches are used to examine the decision making in wood collection.

This research provides a useful framework for investigating resource use because it combines concurrent studies of village and woodland communities. The quantitative and rigorous approach enables the factors that influence resource use, and their impact, to be defined. This study contributes to theories of conservation and the practice of integrated management of natural resources. Furthermore, the research demonstrates the importance of woodland resources to the subsistence strategies of rural communities within a protected area system.

Acknowledgements

I would like to thank the Malawi Department of National Parks and Wildlife (MDNPW) for proposing this project and providing logistical support and housing during my 18 months fieldwork at Lake Malawi National Park (LMNP). I extend my thanks to all the staff at the MDNPW Headquarters (especially Mrs. Warren and the Library Staff) for the warm welcome they gave me. I would particularly like to thank Matthew Matemba (a former student of UCL), Francis Mkanda (who made many useful comments on my research programme) and Simon Munthali (a fellow PhD researcher at the Lake) for the interest they showed in my study. At LMNP, I would like to thank everyone at Golden Sands, all of whom showed me great hospitality, including: my counterpart Pearson Chirambo, Sam Kimoto, Clement Mbota, George Banda, the Chirwa family and Eva.

Permission for this study to be undertaken in Malawi was provided by the National Research Council of Malawi and local permission was provided by the village chiefs, particularly Chief Chembe, to whom I am grateful. The study was funded by the Economic and Social Research Council. Additional financial support for the fieldwork was provided by the Central Research Fund (University of London), the Parkes Foundation (University of Cambridge) and the Boise Fund (University of Oxford). Accommodation in Malawi was provided by the MDNPW. The Graduate School, University College London provided partial funding for me to attend a conference to present two papers from this thesis. I gratefully acknowledge the support of all these organisations.

This study would not have been possible without the co-operation of the people from the enclave villages and I extend my thanks to everyone who participated in the research. The women, in particular, made the project an enjoyable experience and showed unfailing good humour in tolerating their houses being measured and fuelwood bundles weighed. This study would also not have been possible without my village research assistants, Nephat Break and the late Waterson Kazanje, who organised the logistics of the study. Both showed great patience, commitment and humour throughout the research. I acknowledge the assistance of Stanford Chigalu and Brains for their assistance in data collection in Msaka village. I would particularly like to thank all those who assisted in the vegetation survey which was a difficult and demanding task that required a team effort: Pearson Chirambo, Nephat Break, Lyton Gustinyu and Henry Kaiwala. All had a great knowledge of the local flora which they patiently shared with me.

I acknowledge Hassan Patel at the National Herbarium and Botanical Gardens of Malawi for his remarkable skills in identifying trees from my specimens. Furthermore, I would like to thank all the staff at Forestry Research Institute of Malawi (particularly Jimmy Lowore, Patrick Abbot, Mark Lawrence and Ben Siddle) for many useful discussions on forestry but also for the mountain relief provided by Zomba after the heat of the lake. I would like to thank Mr. Kauwa at the Air Photo Interpretation Unit for his kind assistance in the aerial photographic analysis of LMNP. I extend my thanks to Scott Grenfell for his continual encouragement and to the Peace Corps volunteers Lance Smith and Joe Kemmer with whom I worked during my stay at Cape

Maclear. The participatory rural appraisal was greatly enhanced through assistance from Andy Sharpe, Julian Stanway and Jefferson Gulo.

In Chembe, I would like to thank Rose, Mr. Stephens, Nephat's family and all the 'makowedwe' and the children, especially William and Harry, who made my stay at the Lake very special. I would also like to thank a range of people in Malawi who provided me with accommodation and hospitality when I was in town: Nicola Byrne, Emma Richardson, Jason Scott, Nick Heyward, Bob Chesteen, David Foot, Mike Tiernan and Vincent Owen. Particular thanks are due to David Dowse for keeping my car in good condition in spite of the Cape Maclear road! I am especially grateful for the kind hospitality shown by Brian and June Walker, Dennis and Sharon Tweddle and Glen Forester, all of whom showed much interest in this study.

There are many people at UCL who I would like to thank for their support and encouragement and who have provided interesting debate and constructive criticism. Primarily, I am grateful to Georgina Dasilva for encouraging me to undertake this project and deeply regret that she did not live to see the finished thesis. I would like to thank my two supervisors Katherine Homewood and Ruth Mace for providing continual support, interest and advice throughout this research. I also thank Katherine Homewood for reading this entire thesis one-handed and still providing excellent editorial advice. I am grateful to all the participants of the Human Ecology Group who, over the last three years, have provided many useful discussions and have helped me to formulate ideas. I thank all of the Anthropology staff at UCL who have assisted me including: Leslie Aiello, Sara Randall, Simon Strickland, Phil Burnham, Alan Abramson, Fred Brett, Robin Dunbar, Alena Kocourek and Eusebia Michel.

I would like to extend specific thanks to all those people who provided essential assistance in terms of advising on methods, analyses or read earlier drafts of this document: Katherine Homewood, Ruth Mace, Tim Allott, Barrie Goldsmith, Tony Ribbink, Ray Lawton, Derek Eaton, Jason Scott, Louise Barrett, Adam Biran, Emmanuel de Merode, Paddy Abbot, Jimmy Lowore, Eammon Ferguson, Francis Mkanda, Simon Munthali and Hillard Kaplan. The maps were created with assistance from Emmanuel de Merode to whom I am extremely grateful.

My thanks are also extended to those who gave freely of their time and fieldwork anecodotes and provided much encouragement by virtue of having finished their PhDs: Dawn Hartley, Heidi Marriott, Craig Roberts, Guy Cowlishaw, Louise Barrett and Catherine Kenyatta. Particular thanks are due to those with whom I started this PhD and have shared so much of the last three years, especially the original Human Ecology Group members: Adam Biran, Yvette Evers and Pippa Trench. I would also like to thank all the postgrads in the Department who have provided support including: Dan Nettle, Alan Dangour, Hilda Kiwasila and Nilofer Ghaffar. From my Masters course, I thank Cris Edgell, Jem Owen and Rik Fox for their continual interest in my research and many interesting debates on conservation.

Finally, I would like to take this opportunity to thank my family, particularly my parents and grandparents, who provided essential support for my study. I also thank friends who have encouraged me throughout this long task: Maya Twardzicka, Sonia Jackson, Jeff Wollen, Andy Fulton, Tim Buxton, Aidan Webster and Emmanuel de Merode.

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Acronyms

CAMPFIRE	Communal Areas Management Programme for Indigneous Resources
FRIM	Forestry Research Institute of Malawi
GoM	Government of Malawi
LIRDP	Luangwa Integrated Resource Development Project
LMNP	Lake Malawi National Park
MDNPW	Malawi Department of National Parks and Wildlife
MK	Malawi Kwacha, the currency of Malawi
NHBGM	National Herbarium and Botanical Gardens of Malawi
NTFP	Non-timber forest product
PLE	Participatory Learning Exercises
PRA	Participatory Rural Appraisal
RRA	Rapid Rural Appraisal
UN	United Nations
WWF	World Wide Fund for Nature

Author's Note

The views and opinions expressed and conclusions reached in this thesis are those of the author alone and do not necessarily represent the individual or collective views of any of the supporting or funding organisations. Any maps have been prepared for the convenience of readers by the author and do not imply any judgement of the legal status of the boundaries shown.

Chapter 1

Introduction

Summary

This thesis explores the use of natural resources by communities living within a protected area, Lake Malawi National Park (LMNP). Focusing on the *miombo* woodlands, it examines patterns of collection and use of woodland products, the impact of harvesting on the resource base and the role of woodland products in subsistence strategies. Fuelwood is a particularly important woodland resource in the developing world and has been the focus of many research and development projects since the 'energy crisis' of the 1970s. It is also an important resource in LMNP where collection of fuelwood is regulated by the protected area's managing authorities, the Malawi Department of National Parks and Wildlife (MDNPW). However, reflecting recent changes in perspective on the utilisation of natural resources (see below), this thesis takes a multi-disciplinary approach and examines the use of fuelwood in the context of a range of other woodland products and explores the collective role of natural resources in local subsistence strategies.

This discussion draws together studies and theories from a range of disciplines. It outlines the historical context to the study of natural resources and its implications for development initiatives, documenting the changes in methodologies that were required to address the current development approaches. It incorporates the paradigm shift in tropical forestry (see Shepherd 1993), and in development more generally, which may be summarised as a move away from preservation of national resources towards the integrated management of local resources. Furthermore, it addresses specific issues of interest to this research, such as gender, participation, protected area management and the importance of a multi-disciplinary research agenda to explore natural resource utilisation within a woodland setting.

Historical Context and Methodological Approaches to the Study of Resource Use

There is a long history to the study of natural resource utilisation by local communities in Africa. In particular, Nyasaland (now Malawi) was the site of an 'experiment in Multi-sectoral Research and Planning', implemented by the British colonial administration from 1938 to 1943 (Berry and Petty 1992). Similar studies were undertaken contemporaneously in Kenya, Northern Rhodesia (Zambia) and the Gambia. A common element to the 'Nutrition in the Colonial Empire' research was the use of an horizontal or multi-disciplinary methodological approach to study the role of nutrition in development planning, drawing upon a range of disciplines *viz.* agriculture, nutrition, botany, anthropology, economics and medicine. The underlying policy aim was to find sustainable methods of increasing food production and establish more secure subsistence livelihoods. It was reasoned that these would enhance nutritional status, thereby improving health and labour productivity and, simultaneously, stimulate economic growth through production of marketable surpluses.

Although the Nyasaland research programme lasted for five years, the results were not published after the study was completed and the development outcomes never implemented. Thus, the implications and importance of such a comprehensive and integrated study were lost, being superseded by single sector studies in the post-war years (Berry and Petty 1992). The technical fix response to development was one consequence of this more vertical approach to research, where problems and priorities are identified by outside experts (see Berry and Petty 1992, Homewood 1994). For example, post-war nutrition surveys did not attempt the multi-disciplinary field techniques of earlier studies. Instead, they aimed to establish food balance sheets for each colonial territory and identify 'nutrient gaps' (Berry and Petty 1992). Thus, development initiatives, such as nutritional education and supplementary feeding, were prescribed to compensate for the shortfall between food supply and demand. Such approaches were heavily criticised by those advocating a multi-sectoral approach (Berry and Petty 1992).

Forestry Research and Development

A similar approach to development planning is exemplified by the energy crisis of the 1970s, which focused attention on the energy needs of developing countries. In particular, the heavy reliance of both urban and rural populations on wood energy came to the fore during this period, precipitating intense international interest and concern. For example, it is estimated that fuelwood and charcoal account for over 90 per cent of Malawi's primary energy supply (OPC 1988). Various organisations, including the United Nations Food and Agriculture Organisation (FAO, see Eckholm et al. 1984), examined the 'fuelwood crisis' using vertical approaches analogous to the post-war nutrition surveys outlined previously. Their analyses compared estimated fuelwood consumption with the natural growth rates of vegetation and the proportion of fuel that was accessible to, and could be derived on a sustainable basis by, local communities. Fuelwood demand was projected into the next century by incorporating estimated population growth rates. The net result of the analysis was to identify 'fuelwood gaps', areas where fuelwood supply failed to meet demand. These were mapped and the developing world categorised according to the scale of the shortfall: acute scarcity, deficit situation or satisfactory/prospective deficit.

The FAO acknowledged the data sets for the analyses were poor and that the projections were not intended as accurate predictions (Eckholm et al.. 1984). However, the magnitude of the fuelwood crisis and the projected deforestation that would result mobilised international concern. Yet by focusing narrowly on deforestation as an energy-related problem, the proposed solutions were also energy oriented, based on increasing the supply of, or decreasing demand for, fuelwood (Munslow 1988, Mearns 1995). For example, planting trees, particularly fast growing species like *Eucalyptus* spp., was seen as a way of both meeting fuelwood demand and halting the process of land degradation, another environmental concern raised during this period. While plantations were not the only approach, early attempts at community forestry (see below) mirrored classic forestry techniques: rows of primarily exotic species, planted in straight lines and surrounded by fences (Hisham 1991). Other technical fixes to close the fuelwood gap were introduced, including fuel-efficient stoves and solar cookers designed to reduce the demand for fuelwood (Eckholm et al. 1981).

A disadvantage of this single sector approach to the energy crisis was the failure to examine the role of fuelwood in the context of subsistence practices. Moreover, the energy biased solutions also failed to identify the competing priorities and problems of local households or address the multiple local uses of woody vegetation (Mearns 1995). Thus forestry projects were implemented, in areas identified as experiencing fuelwood scarcity, that failed to understand or address local perspectives on the environment. As a consequence, the concerns and priorities of the development initiatives and the local populations did not necessarily correspond.

With the benefit of hind-sight, it is perhaps unsurprising that many of the early initiatives to promote forestry in the developing world had low levels of success. By the 1980s, the technical fix approach to forestry aid was largely superseded by social forestry. This represented a change in emphasis, away from forests for the nation, towards trees for the people (Hisham 1991). Initiatives in social forestry (currently known as rural development forestry), paralleled a more broad change in perspectives on, and priorities for, development. The change in development acknowledged the need for participation by local communities in decision making and a more socially-articulated view of the relationship between people and their environment.

For forestry aid, this resulted in a change from the large-scale rural tree-planting programmes based on the plantation models popular since the 1960s, towards more participatory approaches that address the dynamics of forest utilisation. Shepherd (1993) outlines the history of social forestry which began with communal planting of woodlots and farm forestry and has developed to incorporate participatory woodland management. The latter acknowledges the multi-use functions of forest ecosystems (see also Hisham 1991, Dei 1992). While economic development strategies promote exploitation of forests to secure hard currency, national governments also recognise the need to preserve forests to protect catchment areas and water supplies. Reacting to an emerging environmental agenda, international concerns address the protection of biological diversity. Furthermore, rural populations depend on forest resources to sustain basic livelihoods yet they tend to have been a forgotten element of forestry planning. Thus, it is vital to strike a balance between the competing forces of national and international interests and the needs of rural people. Participatory forest management aims to redress the balance and reconcile the various demands for forest access and use strategies.

Current thinking on people and forestry

Social forestry approaches have highlighted the integrated role of natural resources in subsistence practices (see below) and the dynamics of the people-environment interface. This has led to a rejection of conventional analyses of the longevity of forests based on simple Malthusian models of population growth and estimated average fuelwood consumption and forest standing crop. Soussan et al. (1992) note that the fuelwood crisis is just one of many resource stresses contingent upon a settled population. It should thus be examined in the context of the wider problem of rural poverty, which in itself prompts the clearance of forests for agriculture, for food and income. They suggest 'a reassessment of the resource scarcity paradigm which dominated the 1970s and early 1980s' such that energy should be defined in terms of need rather than resource availability. Similarly, Mearns (1995) rejects physical scarcity of fuelwood for institutional scarcity. He suggests that it is institutions that secure the ability of local people to acquire effective control over domestic fuelwood supplies that are often 'scarce': inefficient or inappropriate social or policy mechanisms prevent households from procuring sufficient wood energy.

Reviewing woodfuel use in East Africa, Mearns (1995) outlines serious flaws in the 'fuelwood gap' analyses for the developing world. Primarily, he levels criticism at the poor data on which the analyses are generally constructed and the assumption that fuelwood collection, rather than agricultural expansion, is the major cause of deforestation. He also notes wide variation in household energy use (depending on climate, altitude, subsistence practices, household size etc.), suggesting that 'woodfuel consumption patterns defy generalisation' and restrict the use of average fuelwood consumption rates. More importantly, he criticises the assumption that fuelwood consumption is inelastic, ignoring the coping responses employed by populations facing fuelwood shortages. For example, Brouwer et al. (1989) describe three main coping strategies that households may adopt to cope with shortages of woodfuel: increased time and energy spent in collection, substitution of alternative fuels and economising on consumption of fuelwood. Yet projections of fuelwood demand fail to adjust fuelwood consumption in response to its availability. As a consequence of combining all the sources of error in the datasets, Mearns (1995) suggests that the conventional analysis has mis-represented and over-generalised the nature of the 'energy crisis' in developing countries.

Other research in Africa suggests that the conventional analysis that precipitated the 'fuelwood crisis' has seriously under-estimated the amount of woody biomass and 'Africa may contain twice as much wood as previously believed' (see Pearce 1994). Past calculations of woody biomass were made by foresters and used utilisation limits for commercial timber based on tree trunks. The utilisation limit for fuelwood is much smaller and incorporates branches and roots, which make up to 60 per cent of the total wood in a tree (cf. Learch and Mearns 1988 pp. 47-51). Furthermore, satellite remote sensing of wood stocks failed to include trees grown on farmplots, which are an important source of woody resources. For example, research by the Beijer Institute's Kenya Woodfuel Development Project suggests that woody biomass (in the form of woodlots, boundary markings, windrows and trees left in the fields) is an integral part of most farming systems in western Kenya and that as population density increases and farm size declines, tree cover actually increases (see Bradley 1991, Mearns 1995).

There has been great concern in Malawi about the rapid disappearance of extensive areas of woodland. Dewee (1995) reports '[t]here is somehow an assumption that vast areas have been converted into wastelands as a result of woodland clearance, mostly to support the expansion of arable agriculture, but at considerable cost to the environment'. He notes, however, that relatively little research has studied the processes that follow agricultural intensification. Rather than clear their farmlands of trees, his surveys show a huge range of tree species in farmplots. Farmers encourage the regeneration of trees in fields and around their households by protecting naturally regenerating indigenous trees, planting tree seedlings and by leaving preferred trees in the field when clearing the woodland for cultivation. These studies suggest that although the subsistence strategies pursued by rural populations modify the environment, this does not necessarily entail environmental destruction. Moreover, subsistence activities in themselves may promote forest growth, providing a source of fuelwood and other resources for the household.

Another study, in West Africa, also challenges the population-led models of deforestation by documenting the ways in which populations enrich and manage their environment. Fairhead and Leach (1995a & b) suggest that forest islands surrounded by savanna owe their existence to inhabitants who encourage forests to develop around savanna settlements. This is in sharp contrast to the conventional interpretation which sees such islands as being relics of more expansive forests. Once again, the conclusion to be drawn is not that populations have no impact on their environment, rather, that people can reduce or enhance vegetation cover depending on specific, local circumstances. Thus, Fairhead and Leach (1995b) examine forest status in each of five West African countries separately to determine the historical context and interplay between populations and their environment. They conclude that demographic factors alone are insufficient to determine human impacts on the environment: 'One...needs not just to know how many people there are, but what they are doing, and what the baseline vegetation was' (Fairhead and Leach 1995b).

These studies highlight the importance of local conditions in defining the nature of resource use and stress (see Shepherd 1993). Specifically, a number of socio-economic and ecological factors (e.g. demand for woodland products, land tenure, coping strategies, the nature of subsistence practices, topography, climate etc.) act at a local level to influence the interaction between human communities and their environments (Soussan et al. 1992). Consequently, the ways in which populations control their land and manipulate their environment are important dimensions to the study of resource use. Pimbert and Pretty (1995) summarise recent thinking on the interactions between rural people and their environment, in what they term 'humanised ecosystems', thus:

> 'Anthropogenic influence has often actively maintained and enhanced biological diversity in forests...and other environments from which rural people have historically derived their livelihoods. Recent findings in ecology suggest that nature is in a state of continuous change. The importance of disturbance is increasingly acknowledged for the maintenance of biological diversity and other fundamental ecological processes. Some of these changes are in part random and independent of each other, while others are human induced.'

These current views challenge the static view of populations and forests held by conventional forestry approaches and contest the underlying assumptions in a population-led model of deforestation. Instead, they present a more dynamic, locally defined relationship between people and their environment, in which both components can respond to changing circumstances.

An integrated approach to forestry

The lessons learned from development reactions to the energy crisis of the 1970s demonstrate the importance of an holistic approach to analyse the problems of resource use. Similar to the research approaches used much earlier this century (see Berry and Petty 1992), it is increasingly recognised that multi-disciplinary studies are vital to gain an understanding of subsistence practices and ways to improve development assistance (see Harrison 1995). With a move away from the energy-biased view of forests, the links between forestry and other disciplines, particularly nutrition (Ogden nd), are increasingly recognised.

Forest products, such as wild foods, play an important role in smallholder economies, contributing directly to household food security, through their consumption or use for income generation (Okigbo 1986). However, fuelwood is also a resource that impacts upon food security and rural livelihoods. Poulsen (1981) and Brouwer et al. (1989) suggest that the smallholder's basic problems of producing sufficient food and having access to appropriate energy sources to enable its cooking cannot be solved in isolation from each other. Fuelwood, as the main source of energy in developing countries, is essential to make food suitable, by cooking, for human consumption.

The potential nutritional impacts of a fuelwood shortage on rural households in developing countries have been outlined by Brouwer et al. (1989). They suggest that the additional time invested in fuel collection affects food supply, preservation, preparation and consumption. The consequences include a decrease in the quality and quantity of food consumed, reduced opportunities for income generation and a deterioration of physical condition, especially among women (the main fuelwood collectors, Spring 1988) and their children.

Thus it appears that in many rural areas in developing countries, forests and trees play an important role in subsistence practices and contribute to household food security (see Falconer and Arnold 1991). The latter is not simply a problem of agricultural output, contrasting food supply and demand in a balance sheet approach, but encompasses all factors that affect a household's access to an adequate year round supply of food (Falconer and Arnold 1991). Numerous studies document the contribution of natural resources, particularly forest products, to household economies (see Fleuret 1979, Malaisse and Parent 1985, Campbell 1986, 1987, Guinko and Pasgo 1992, Scoones et al. 1992). But it is clear that environmental factors (e.g. the availability of water, fuelwood and a range of natural resources) and socio-economic determinants (e.g. access to resources and markets) influence the ability of households to secure adequate food supplies.

Non-timber forest products

A significant botanical and anthropological literature addresses ethnobotany, the usefulness of plants and plant substances to human communities (Fleuret 1980, Prance 1991, Martin 1995). An in-country example is Jessie Williamson's (1974) 'Useful plants of Malawi' which outlines indigenous plant species used as foods and medicines. More recently, and concurrent with the advance of social forestry approaches, numerous studies have begun to document the role of forest products in subsistence practices. For example, an annotated bibliography 'The Hidden Harvest' (Scoones et al. 1992), contains over nine hundred references on wild foods and other resources and the ways they contribute to agricultural systems.

The terms 'minor forest produce' (Koppell 1990), 'secondary forest products', 'non-wood products' (Peters et al. 1989) and 'non-timber forest products' (NTFPs) have been used to encompass a range of forest products. These include wild foods, building materials, fibres, fuelwood and other tree and forest resources that are harvested by rural communities, either to use directly or as a source of income. This terminology also embraces animal resources, such as bushmeat and insects (Asibey and Child 1990, Munthali and Mughogho 1993). Falconer (1992) defines NTFPs simply as any products, excluding commercially exploited timber, gathered from forests whether for commercial or subsistence purposes.

Falconer and Arnold (1991) summarise the major functions of NTFPs as:

- augmenting farm production (diversifying the diet, increasing the quality of nutrition through provision of essential nutrients and energy-giving snacks, supply of fuelwood and opportunities for income generation through forest based enterprises)
- supplementing seasonal short-falls in food and income (see Fleuret 1979, Campbell 1987)
- providing a buffer during hardship periods (risk reduction through provision of 'famine foods', Vaughan 1987, Berry and Petty 1992).

Pimbert and Pretty (1995) note that while it is acknowledged that hunter-gatherer groups depend on wild resources, the heavy reliance of subsistence farmers on wild resources is less well recognised and understood. Yet most rural people have an extensive knowledge of plant resources and management of the environment (Prance 1991). 'Indigenous knowledge' of traditional plant uses and resource management practices can make a significant contribution to assessing the economic value of biotic resources and establishing effective management strategies (Medley 1993). Hence, there is a large, emerging literature that documents local patterns of use of NTFPs (e.g. Nepstad and Schwartzman 1992). However, for such research to contribute to community conservation strategies, it is important to document the ways in which different products are used, rather than produce inventories of utilisation. In particular, there is a need to contrast the use of forest products with other sources of income and detail the ways in which NTFPs contribute to subsistence practices and are used for income generation (cf. Scoones et al. 1992).

Moreover, the impact of harvesting on the resource base is important since this determines the sustainability of harvesting activities.

Thus, it is clear that a comprehensive study of the role of NTFPs in subsistence strategies requires a multi-disciplinary approach, combining methodologies from the natural and social sciences. The need for such an approach is outlined by Hughes (1988) with regard to fuelwood, however her comments are equally applicable to other forest products:

> 'There has been an increase in the number of studies carried out on patterns of fuelwood use, but in many ways they provide us with little new information if they do not relate use to availability. Whilst studies of fuelwood use have tended to be carried out by social anthropologists and socio-economists, studies of timber production have been carried out by foresters in plantations and by no-one in natural woodlands and forests. The gap in knowledge between fuelwood demand and supply is a serious one, since it makes sustainable management of existing supplies....very difficult. It is a gap which is created partly by the.....fact that most studies follow one line of research instead of being interdisciplinary in nature'.

While a static view of the supply and demand for woodland products may provide a too simplistic model of resource use (as outlined above), a multi-disciplinary study is required to examine resource use and the impacts of harvesting practices on the resource base. These data are important for the integrated management of forest resources.

Integrated Management of Natural Resources and Protected Areas

A key feature of the World Conservation Strategy (IUCN 1980), and extensively developed by the follow up document Caring for the Earth (Munro and Holdgate 1991), was a move away from 'fortress conservation' and wildlife ~~preservations~~ preservation towards a more integrated role for protected areas. Their new role is to maintain biodiversity, consistent with the original aim to conserve the resource base, but to provide simultaneously, sustainable economic returns to local people. Community management of natural resources, epitomised by the Communal Areas Management Programme for Indigenous Resources in Zimbabwe (CAMPFIRE) and the Luangwa Integrated Resource Development Project in Zambia (LIRDP), have been heralded as a panacea to unite conservation and development (Swanson and Barbier 1992, IIED 1994).

Traditional practices of extracting non-timber forest products (NTFPs), which leave the forest structurally and functionally intact, have been advocated for conserving tropical forests and providing sustained benefits to rural communities. Harvesting NTFPs from forest reserves is appealing because it provides economic, ecological and social justifications for the maintenance of protected areas. The practice of NTFP extraction came to the fore during the late 1980s when a grass-roots movement of autonomous rubber-tappers in Brazil fought to protect their lands from encroaching cattle ranchers (Nepstad and Schwartzman 1992). Although, the concept and practice of extractive reserves is more highly developed in Latin America, it has been applied elsewhere, including Africa and Asia (Salafsky et al. 1993, IIED 1994, see below).

For example, for people living in and around Korup National Park, Cameroon, NTFPs constitute the most important source of income (Amadi 1993). Developing rural industries for local people based on the sustainable use of forest products is one of the aims of The Korup Project (an alliance between the Cameroon Government and World Wide Fund for Nature, WWF). Poor communication was identified as an obstacle for local people in marketing forest products. Thus, a farm-to-market road is being constructed to facilitate trade in relatively heavy but low value forest products and food crops. While the resettlement of local people remains a contentious issue in this area, developing markets for NTFPs appears to be an important method of reconciling conservation and development strategies.

Historically, honey hunting and traditional bee keeping has been an important part of the subsistence economy of people residing within *miombo* woodlands of central and southern Africa (Fischer 1993). The potential for extractive reserves based on the harvesting of this high-value product has begun to be realised in Malawi and Zambia. For example, the German Embassy and WWF have developed bee keeping as a viable alternative source of income for people living in proximity to Vwaza Game Reserve and Nyika National Park, Malawi. Through the establishment of bee keeping clubs, rural people have controlled access to the protected areas, which has improved the relations between villagers and the conservation authorities (see Adams and McShane 1992, IIED 1994).

However, while extractive reserves are heralded as a 'new' approach to conservation, it is interesting to note that the colonial administration in Malawi recognised the importance of forest products (including fuelwood, poles and ropes) for local people. Clements (1935) reviews the Nyasaland forestry policy thus: 'it had long been evident that reservations of forest as State reserves could not be carried out on a scale sufficiently comprehensive to provide for a sustained yield of forest produce for the large native population'. Recognising that local communities were unable to pay for forest products and that planting of exotic species was unlikely to meet their needs, it was decided in 1925 to establish a system of communal forests. Patches of woodland known as Village Forest Areas were demarcated and allocated to village headmen for protection and management. The size of these areas depended upon the number of huts in the village on a basis, where possible, of two acres of woodland per hut.

An understanding of patterns of resource use is central to the integrated management of natural resources. Yet theoretical views on the conservation of common property resources are varied. Economic theory predicts that open access or common property resources are subject to the 'tragedy of the commons' where the benefits to the individual are maximised by exploiting the resource given that the costs of over-exploitation are incurred by the group as a whole (Hardin 1968). This is consistent with evolutionary theory which 'finds little theoretical justification for expecting individuals to conserve open access resources' as individuals should act in ways to benefit their own, rather than the group, interests (see Alvard 1993 for a discussion). By contrast, other researchers believe that traditional authority, local and cultural institutions, customs and taboos act to conserve common property resources and prevent the degradation associated with open access to natural resources (Berkes 1989). An important distinction between Village Forest Areas and State forests in Malawi was that access was controlled locally recognising that 'the chances of success of a communal forest scheme would depend almost entirely upon a sense of ownership and freedom from legal restrictions' (Clements 1935). Just ten years after the scheme was introduced Clements (1935) commented 'reports from all the districts indicate that at present there is no tendency to over-fell,.......because the areas belong to small communities a strong sense of ownership and emulation is developing in connection with them. Prompt legal action has been taken by some headmen regarding damage or unauthorised cutting in their areas by people from other communities'. The future success or failure of extractive reserves developed more recently is also likely to depend, to a large extent, on the ability of traditional and novel community controls to enforce harvesting practices.

Gender Aspects of Resource Use

The household is the conventional unit of study in subsistence economies (Ellis 1988). This is a convenient social unit to analyse subsistence practices but overlooks the heterogeneity of the household as a unit, particularly with regard to the gender division of labour. The rigidity in the latter inhibits the substitution of male and female labour in subsistence tasks and thus determines the time allocation of men and women. As the control over resources often resides in the male head of household, attention has focused on men and, until recently, the role of women in subsistence production systems tends to have been ignored.

Historically, the colonial authorities in Malawi assumed a male-headed, nuclear household structure as the unit of production and consumption, within which food was shared equally. They therefore applied unmodified eurocentric models of development even though the matrilineal *mbumba* was the basic social unit, consisting of a group of sisters and their children (Vaughan 1987, Harrison 1995). The matrilineal system was important at that time because many males were absent, either working on other farms or in South African mines. This trend continues today: one-third of households are female headed both nationally (UN/GoM 1993) and locally (author's unpublished data). Despite the 'loosening' of social structures (Harrison 1995), southern Malawi still has a matrilineal system. However, control over land ownership and inheritance tends to be overseen by male relatives, in particular maternal uncles or elder brothers, in whom decision making power is vested (UN/GoM 1993).

More recently the evolution of the women's movement, manifested in the United Nations Decade for Women, has changed the way development issues are defined (Kardam 1991). It has been increasingly recognised that women are the *de facto* food producers in the developing world (see Dankelman and Davidson 1988). Thus, strategies to alleviate poverty must necessarily embody a gender dimension with an explicit focus on women, as activities to enhance food security fall within the domain of women's productive activities. It is reasoned that the main constraints on female productivity are related to their labour in daily household maintenance tasks and a reduction in time allocated to these tasks increases the time available to invest in income generating activities. Moreover, increasing women's access to income is likely to have greater welfare benefits for the household, particularly children, than an equivalent income generated by men (Kandyoti 1987). Furthermore, Kainer and Duryea (1992) report that the inclusion of women in the development process has resulted in greater project success and efficiency.

Dankelman and Davidson (1988) explore the relationship between women and the environment. They document that the use of natural resources (including soil, water and forests) is an integral part of household daily maintenance tasks which are undertaken predominantly by women. It should not be inferred from this that women have a more natural affinity than men with nature as advocated by eco-feminism, the theoretical perspective derived from a philosophy of women (see review by Barrett and Browne 1995). Rather, their role as 'environmental resource managers' is derived from the gender division of labour in the household. This requires women to have greater use of the environment and thus, greater potential for the destruction or conservation of its resources.

As a reaction to the exclusion of women from early agendas of analysis and research, a gender component has been a key theme of recent development theory. But this has focused almost exclusively on women, to the point that the term 'gender' is almost synonymous with 'women' and the relationship between men and the environment overlooked. It is thus important to strike a balance and recognise that women and men often have distinct skills and knowledge relating to the use of natural vegetation, usually the result of the gender division of household labour and responsibilities. Kainer and Duryea (1992) note that an understanding of the differences in natural resource knowledge are crucial when defining directions for future research and action in extractive reserves. For example, from their research in Brazil, they note that women process almost all the plants used by the household and its animals, while the collection of construction materials and fuelwood are generally male activities. However, the gender division of labour in this case was not rigid, with women assisting on many of the male dominated tasks. It was also observed that women demonstrated great desire to enter into the market economy, a positive feature for local initiatives to develop participatory forest management and extractive reserves.

Participation in Protected Area Management

An important theme for the integrated management of protected areas is the involvement of local communities in the decision making process. Hisham (1991) notes that participation has become a buzzword of the development literature although it is difficult to define and is thus characterised by different interpretations. Pimbert and Pretty (1995) note that during the colonial period, conservation was characterised by control and management of 'natural ecosystems' from which local people were excluded. Subsequently, participation was used as a tool for achieving a fixed agenda, in which local people were passive actors. They suggest that during the 1980s, participation became increasingly linked with community inclusion in the protection of natural resources. More recently, it has been recognised that community participation is a critical component for the success of conservation projects. Thus participation is currently a method of involving people in protected area management. However, there are many ways in which development organisations interpret and use the term participation. Pimbert and Pretty (1995) suggest that the term should be interpreted cautiously and not used without clarification. Pretty (1993, in Dalal-Clayton and Dent 1993) has derived a seven point typology of how people participate in development programmes and projects. These range from manipulative participation (in which local people act out pre-determined roles) to self mobilisation where people take initiatives independent of external organisations.

In the context of this thesis, participation refers to an informal approach to research within the local communities. Participatory research techniques were employed that were inevitably initiated from outside but which aimed to enable local people to explore and analyse their own experiences. The use of these techniques in the early phases of the research project enabled a research programme to be designed that addresses local agendas. While this approach constitutes participation by consultation, it does not reflect the full, interactive participation that appears to generate the best, long term results for development projects (see Pimbert and Pretty 1995). However, by addressing the concerns of local people, this research provides substantial baseline information on which future initiatives in community conservation within LMNP can be based. In particular, participatory research methods have been employed to implement Joint Forest Management (JFM) programmes. These programmes enhance community-forest relationships and help secure improved participatory management strategies between user communities and managing authorities (Poffenberger et al. 1992a, 1992b). Soussan et al. (1992) advocate such a bottom-up approach to resource management to give local communities effective control over their local resource base and to empower those social groups at the sharp end of resource stress who typically have little control over land management.

Summary and Thesis Format

This introduction has outlined the changing approaches to natural resource management, focusing on forest products, particularly fuelwood. It has stressed the importance of a multi-disciplinary approach to address the integrated role of forest products in subsistence strategies. The chapters that follow address the issues that have been outlined within this discussion. Chapters 2 and 3 describe the study site and give an overview of the methodologies used in this research project. Chapter 4 summarises the findings of participatory rural appraisal, a range of techniques employed to describe patterns of collection and use of NTFPs within LMNP, including gender differences in resource use.

Quantitative data analysis is presented in Chapters 5 - 9. Chapters 5 and 6 explore the impact of human communities on the resource base. Chapter 5 uses multivariate analyses to interpret the floristic composition of the woodland in terms of land-use practices. The results of aerial photographic analysis of the Park woodlands are presented in Chapter 6. This chapter also presents quantitative data on patterns of collection and use of woody products. These are used to infer the impact of different patterns of harvesting on the resource base.

Gender aspects of resource use are addressed throughout this thesis. Chapter 6 undertakes a quantitative analysis of gender differences in the collection and use of NTFPs which are initially revealed by the participatory research presented in Chapter 4. In the context of community management of natural resources and the concept of extractive reserves, urban and local marketing of forest products is explored in Chapter 7. This is discussed in relation to the economic opportunities available to both men and women. Later chapters explore the collection of domestic fuelwood, which is an activity undertaken predominantly by women who may be assisted by their elder daughters. Fuelwood collection is discussed in terms of the household labour budget and its implications for household size (Chapter 8) and the decision making in wood collection within a protected area (Chapter 9). Chapter 10 summarises the findings of this thesis and discusses the implications of the research in the context of the current literature.

Chapter 2

An Introduction to Malawi and the study site at Lake Malawi National Park.

Malawi is a small, landlocked country in southern Africa, lying between latitudes 9° and 17° South and longitudes 32° and 36° East, at the southern end of the Great East African Rift Valley (see Figure 1). It extends over 118 500 square kilometres, of which 80 per cent is land and the remainder is water, dominated by Lake Malawi. Malawi lies wholly within the tropics, but its heterogeneous topography (ranging from 37 - 3000 metres above sea level) gives rise to highly variable temperature, rainfall and vegetation. There is a marked seasonality of climate with a dry season from May to November, and a wet season from November to April.

Socio-economic Context

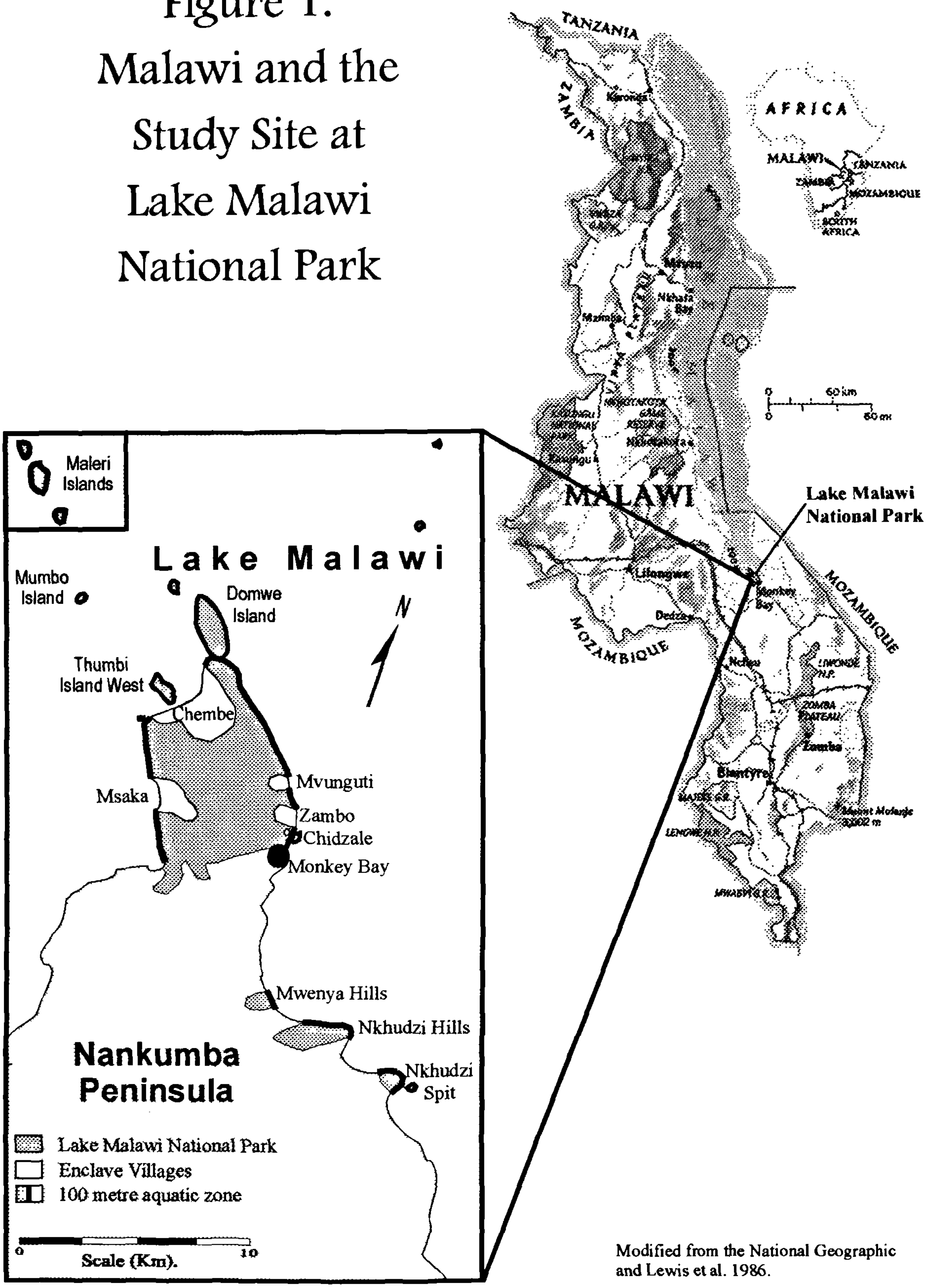
Malawi has a population of approximately 9 million (UN/GoM 1993) and an average population density of 85 persons per square kilometre, exceeding that of its neighbours and most other African countries. The intercensal growth rate is reported as 3.7 per cent *per annum*, evenly distributed across the three administrative regions, Northern, Central and Southern. However, the population is unevenly distributed with 50 per cent concentrated in the Southern Region, with a population density of 125 persons per square kilometre. Just 11 per cent of the population is urban and of these 8 per cent reside in the four cities: the commercial centre of Blantyre, the capital city of Lilongwe, Mzuzu and Zomba (UN/GoM 1993).

Rapid population growth presents a formidable challenge to Malawi, putting pressure on the single most important resource, agricultural land. Agriculture dominates Malawi's economy, accounting for 37 per cent of its Gross Domestic Product (GDP), about 90 per cent of its exports and approximately three-quarters of total employment (Malawi Government 1985, UN/GoM 1993). The climatic diversity facilitates cultivation of a variety of crops including maize, the dominant food staple, millet, sorghum, cassava, pulses and groundnuts. The major export crops are tobacco, tea and sugar. Despite early and rapid economic growth since Independence in 1964, Malawi remains one of the world's least developed countries (LDCs), with a *per capita* GNP of approximately US $210 (Malawi Government 1985).

Malawian agriculture is characterised by both small-scale and estate sectors. The small holder sector is primarily subsistence-oriented and provides the bulk of food production. It comprises approximately 1.6 million families farming approximately 1.8 million hectares. Until recently, Malawi was generally believed to be self sufficient in food staples through inland production (Weaver 1984, Malawi Government 1985). Unlike other developing countries, large food imports were unknown in Malawi until the late 1980s (Walter 1988). However, recent research stimulated by the 1991/92 drought, demonstrates that food production has not kept pace with population growth (see MacAskill 1993, UN/GoM 1993). Food production in 1990/91 was not significantly different from 1980 yet during this period the population almost doubled, reducing the mean household landholding (MacAskill 1993). Households with less than one hectare cannot meet their food requirements using traditional agricultural practices. Yet the Food Security and Nutrition Bulletin (OPC 1988) report that 56 per cent of smallholders have less than one hectare and 26 per cent have less than half a hectare. Thus, household food insecurity appears to be a feature of the smallholder sector (see Chapter 4).

The period of seasonal food scarcity in Malawi coincides with a peak in demand for agricultural labour associated with harvesting food stocks. Smallholders who produce insufficient food to meet their requirements resort to a number of coping strategies to provide sufficient income to purchase food. These include casual labour (*ganyu*), cultivating cash crops, or initiating businesses such as brick making (during the dry season), fishing and keeping livestock. Other activities include weaving, beer brewing, selling firewood or making charcoal (MacAskill 1993). Although there are limited economic opportunities for rural households, informal sector employment makes an important contribution to rural economies, supplementing subsistence agriculture (see Chapters 4 and 7).

Figure 1.
Malawi and the Study Site at Lake Malawi National Park



Modified from the National Geographic and Lewis et al. 1986.

Environment

Malawi lies within an extensive belt of dry, deciduous woodland, known as *miombo* that stretches across the Zambezian Region of central and southern Africa (White 1983, Shorter 1989). It is dominated by tree species of *Brachystegia*, *Julbernardia* and *Isoberlinia*. This woodland formation, often interspersed with evergreen to semi-evergreen forest types, shows considerable variation in structure and composition, reflecting variation in climate, altitude, and soils (Jackson 1968). Currently, the forest resource of Malawi (incorporating both indigenous woodland and plantations) covers approximately 38 per cent of the country, representing 4.5 million hectares (Kayambazinthu 1988). Of this, 11 per cent is designated within national parks and game reserves, 10 per cent is gazetted in forest reserves and protected hill slopes, and the remainder (17 percent) on customary (communal) land.

Agricultural expansion in Malawi, estimated at 3.5 per cent per annum, has precipitated a recent and rapid decline in extensive areas of woodland in Malawi, evoking great concern for the future of the woodland resource base (Dewees 1995). Other factors that have contributed to the demise of indigenous woodland include urban expansion, the influx of Mozambican refugees, rural encroachment and afforestation programmes using exotic tree species (Kayambazinthu 1988).

Lake Malawi National Park

Lake Malawi is the southernmost basin in the African Great Rift Lakes system and contains the most diverse community of freshwater fishes in the world. Lake Malawi National Park (LMNP) is situated in Malawi's Southern Region and was established in 1980. The objective of LMNP is to preserve a sample of the Lake Malawi biome, with particular reference to the cichlid fish communities (LMNP Master Plan 1981). The Park is centred on Nankumba Peninsula at the southern end of Lake Malawi, but includes twelve islands and an aquatic zone extending 100 metres from all Park shorelines (see Figure 1). The Park covers just 94 square kilometres, of which 87 square kilometres are terrestrial and 7 square kilometres comprise the aquatic zone.

The park aquatic zone consists of a rocky shoreline falling steeply into the lake, with the substrate varying from large boulders to broken rubble, often giving way to sand between five and forty metres in depth (Smith 1993a). The most conspicuous and diverse fish in the aquatic zone are the *mbuna* (small, colourful rock-dwelling cichlids) with over one hundred species in the Park area alone (Lewis et al. 1986). The diversity of the *mbuna* is attributed to fluctuations in lake levels which isolated small founder populations and led to their rapid divergence (Owen et al. 1990). As a consequence, these fish are of great ecological interest and evolutionary significance. Most research within LMNP has focused on the adaptive radiation of the cichlids and the effects of fish introduced from other parts of the Lake for the aquarium trade (see Lewis et al. 1986, Grenfell 1993). However, the aquatic habitat also supports a diverse population of birds and animals, including the African fish eagle (*Haliaeetus vocifer*), the white breasted cormorant (*Phalacrocorax carbo*), the Cape Clawless Otter (*Aonyx capensis*), Spotted-necked otter (*Lutra maculicollis*), monitor lizards (*Varnus niloticus*), crocodiles (*Crocodylus niloticus*) and hippopotami (*Hippopotamus amphibius*).

The terrestrial fauna has been less well studied, but the Park contains several species of smaller mammals including: klipspringer (*Oreotragus oreotragus*), common duiker (*Silvicapra grimmia*), rock hyrax (*Procavia capensis*), civet (*Civettictis civetta*) and three primate species: baboons (*Papio ursinus*), vervet monkeys (*Cercopithecus aethiops*) and, in less disturbed areas at higher elevations, blue (samango) monkeys (*Cercopithecus mitis*).

While established as an aquatic park, 93 per cent of the designated area is terrestrial (Grenfell 1993). The Park incorporates five traditional fishing villages (Chembe, Msaka, Mvunguti, Zambo and Chidzale) distributed along the shores of the peninsula. The population is estimated at 8 440 people (Independent Census 1994), giving a population density of 122 people per square kilometre of the Park on the northern tip of Nankumba Peninsula. Although not gazetted within LMNP, each village is encased by the protected area (see Figure 1). The Chewa are the traditional and dominant ethnic group within the villages. But they are outnumbered by a collective of seven other ethnic groups, particularly the Tonga and Tumbuka from Malawi's Northern Region (Grenfell

1993, author's unpublished data). Fishing is the primary economic activity within all the villages. The Chewa also practise subsistence agriculture but landholdings are small (approximately 0.6 hectares), and the short rains and high temperatures associated with the lakeshore, make agriculture marginal.

The villagers depend on the woodland for forest produce, especially fuelwood and building materials. In contrast to most Malawian National Parks, because the villages are encased by the protected area, the Park's policy is to permit dead fuelwood collection by the local population. Indeed, His Excellency, Dr. H. Kamuzu Banda, the former President of Malawi, approved the Park only on condition that its creation 'did not materially interfere with the way of life of the inhabitants of the area' (Bell 1978).

A management objective for LMNP includes 'the protection of steep surfaces....so as to minimise [soil] erosion and siltation of the lakeshore waters' (Clarke 1983). The steep rocky slopes on the hillsides support dry, deciduous open canopy *miombo* woodland, dominated by *Brachystegia microphylla*. The management objective implies conservation of these plant communities, the relationship between vegetation and erosion being well documented in the literature (see for example, Bootsma 1987, Thornes 1990). This is summarised by Nortcliff et al. (1990) thus: '[i]n recent years quantitative proof has been provided of what has been taken for granted for decades: that removal of vegetation cover significantly enhances erosion.....both runoff and sediment yield fall exponentially as the percentage of vegetation cover increases in a wide range of environments.' Despite the terrestrial management objective, the terrestrial component of the Park has not been well studied.

The only two vegetation studies undertaken within LMNP document serious woodland degradation, attributed to fuelwood harvesting by the local communities (Bell 1978, Bootsma 1987). Although the cutting of live trees was made illegal on establishing LMNP, a permit system was introduced for fuelwood collection. Villagers purchase permits from the National Parks Department (cost 30t, 100t = MK1, MK25 = £1), allowing them to collect one headload of dead wood from the woodland. Scouts patrol the woodland to detect illegal wood collectors. Women are the primary collectors of domestic fuelwood and claim to be unable to afford a permit each time they collect fuelwood. If detected by scout patrols, illegal wood collectors risk penalties ranging from warnings or fines, to the more severe confiscation or burning of bundles. The permit system was introduced when the Park was established as an interim measure until alternative sources of fuelwood could be supplied to the villages (see below). However, the cost of the permits and penalties imposed for illegal wood collection have led to strained relations between enclave villagers and the managing authorities of LMNP.

In the LMNP Management and Development Plan, Grenfell (1993) stated that 'One of the greatest threats to the park is the effect of deforestation on the steep slopes of the Nankumba Peninsula.' Preliminary forestry research has been undertaken by Bell (1978) and Bootsma (1987), however neither of these studies assessed local patterns of use of woodland products in the enclave villages and the impact of harvesting on the resource base. Bell (1978) estimated firewood consumption by the peninsula villages and stated that 'within 30 years, a fuel wood crisis will occur in the area'. He recommended the formation of an exotic tree species plantation outside the National Park, with trucks to transport fuelwood to the enclave villages. This did not occur. A more recent European Economic Community proposal ('Nankumba Peninsula Fuelwood Project', GoM 1989), with similar objectives, failed to be funded. In the interim, WWF have introduced village-centred tree nurseries (Grenfell 1993). While the community based initiative is desirable, its scale has been too small to meet local requirements for woody resources.

LMNP is a site of great ecological and evolutionary importance yet the subsistence and economic activities of the enclave villagers depend directly on natural resources and impact on both the terrestrial and aquatic habitats of LMNP. These communities are subject to severe resource stress: agricultural land is both limited and marginal, access to the *miombo* woodland is controlled by the protected area's managing authorities and the fishing industry is declining (Smith 1993a). While the rock-dwelling cichlids are not a target of the fishing industry, these fish may be incidentally caught (a 'by-catch') by fishing close to the Park's off-shore islands (Smith 1993a). A further threat to the cichlids is indirect and stems from degradation of the *miombo* woodlands. Erosion caused by a reduced vegetation cover is thought to cause siltation and alteration of the prime aquatic habitats of the cichlids. A particular threat appears to be sediments coating the algae which are a prime food source for the cichlids (MFNR 1995). The specialised feeding habits of the cichlids suggests they are unable to cope with extensive habitat change. Furthermore, a decline in forest cover is both aesthetically undesirable for the most popular National Park in Malawi (Jalale 1993, cf. Emerton 1995a) and impedes the ability of local people to harvest forest products (Grenfell 1993). An extensive study of the village fishery has recently been undertaken (see Smith 1993a). This study documents community use of the terrestrial component of the Park and the impact of harvesting woody products on the resource base. Thus, the present study focuses on the northern tip of Nankumba Peninsula where village settlements are encased by the protected area.

Chapter 3

Methods

As outlined in Chapter 1, a study of the use and management of natural resources by local communities requires a research programme that can address the integrated problems of subsistence practices and their impact on the resource base. Thus, this study takes a multi-disciplinary approach to explore patterns of use of woodland products and the impact of harvesting practices on the resource base. By measuring utilisation at the level of the household, the market and the resource base, this study attempts to assess both the ecological and socio-economic impact of resource use.

Until recently, there has been little integration of theories developed in the social and natural sciences (cf. Chambers 1983, Homewood 1994). Yet, by adopting a multi-disciplinary approach and combining qualitative and quantitative data collection techniques, the integrated problems of rural poverty can begin to be addressed. This study uses methodologies from three main disciplines: anthropology, ecology and conservation. Furthermore, the study combines participatory research methods with more formal socio-economic and ecological measurement techniques. Each of the methodologies employed in this study is described in more detail in the chapters that follow. This chapter is designed to provide an overview of the methods used and outline the ways in which the different methodologies have been combined.

Participatory Methods

There is increasing recognition that the participation of rural people in the development process is of crucial importance (FAO 1989). This research project was undertaken under the auspices of the Research Unit of the Malawi Department of National Parks and Wildlife (MDNPW), in collaboration with the Management and Education/Community Extension Units based at Lake Malawi National Park (LMNP). A participatory approach to data collection enabled a broad assessment of resource use and the role of woodland resources within the subsistence economy to be made. Participatory research tools also provided a forum through which I was able to introduce myself to the enclave villages. Thus, they were of primary importance during the first (pilot) phase of fieldwork. However, they continued to be used throughout the study to explore specific issues in resource use that were uncovered as the study progressed. Wealth ranking (Grandin 1988) was used as a participatory method of assessing relative income between households. Participatory research methods tend to be less intrusive on the community than formal research methods because they enable the participants to explore and analyse their own environment rather than passively respond to a pre-designed survey. Thus, I found people willing to join in these sessions, older people particularly were happy to recount their experiences and provide oral testimony (Slim and Thompson 1993). Another advantage of these methods was that they enabled me to explain the purpose of the study to the communities and discuss restrictions on resource use imposed by the MDNPW. A range of other, more formal, data collection techniques ~~were~~ was used to complement the participatory methods and explore the issues raised during the learning exercises.

Ecological Methods

Aerial photographic analysis (Spurr 1960) was used in conjunction with oral testimonies (Slim and Thompson 1993) to provide an historical perspective on resource use. The categories used for aerial photographic analysis divided woodland into two main types: sparse woodland and closed canopy woodland. Subsequently, a quadrat based woodland survey (Goldsmith et al. 1986) was employed to provide a current, albeit static, portrait of the floristic composition of the Park woodlands.

Dead wood is an important fuelwood because of its superior burning properties (Dankelman and Davidson 1988). Thus, permanent quadrats were established to monitor the quantity of fallen dead wood produced under *miombo* woodland (cf. Shackleton 1993). The quadrats were clearly marked and the village chief requested villagers not to collect fuelwood from the demarcated areas. At the beginning of each month, all the fallen dead wood within the quadrats was collected and weighed.

Anthropological Methods

Focal subject follows (Altmann 1974) were employed to explore patterns of use of forest products. Groups of wood collectors were accompanied on their fuelwood collection trips and the amount of wood collected and the journey made recorded.

These data are linked with those on habitat quality, as determined by aerial photographic analysis, and the records of scout patrols (see below) to assess the factors that affect patterns of wood collection.

A sub-sample of thirty households from each of two villages within the Park were selected randomly to participate in household surveys (Casley and Lury 1987). Houses were measured to assess the quantity of woody products used in their construction. A record was made of the tree species (and their uses) occurring within the household and farm plots. The amount of fuelwood utilised per week was measured each month, by weighing the fuelwood stockpile and recording all fuelwood brought to the household over the seven day monitoring period. Changes in woodland cover, as measured by aerial photography, are interpreted in terms of patterns of use of woody products within the villages.

Socio-economic data on the focal households were collected, including the principal income generating activities of the women. These data are linked with market surveys (Martin 1995) to explore the potential for marketing forest products. Market surveys examined the availability and price of woodland products traded in the markets. Semi-structured interviews (Oppenheim 1992) with vendors provided information on the trading strategies.

Conservation

Methods for monitoring illegal activity and examining the efficacy of poaching patrols have been developed by Bell (1984). A monitoring system was introduced to record all scout patrols, their encounters with illegal activities and the outcome of the encounters i.e. the action that was taken. These were used to examine the risk posed by the Park patrols and its impact on the wood collection decisions made by wood collectors.

Other Methods

The use of fuelwood by fish smoking stations was also recorded. Four fish smoking stations in Msaka village were monitored, recording the size class, quantity and species of wood utilised over a one week period. A count was also made of the number of fish smoking stations in all of the villages, together with the ethnic origin of the owner of the fish smoking station.

A population survey was undertaken in all five villages. This used the same researcher as employed by the independent census co-ordinated by WWF in the previous year and who had participated in the most recent national census. Thus, the population data are likely to reflect real population change rather than be a function of inter-observer variability. The ethnic origin of each of the households was recorded in the latest population survey.

Summary

This chapter has outlined the various methodologies used during an eighteen month period of fieldwork undertaken in LMNP. The methods are more fully explained and appraised within the chapter that first draws upon its results. The schedule for the fieldwork within the PhD programme was as follows:

- **October 1992 - March 1993** Literature Review and Development of Field Methodologies
- **March 1993 - May 1993** Pilot Study in Malawi. Visits to all five enclave villages, participatory rural appraisal initiated and testing of formal research methods
- **June 1993 - August 1993** Review of Methods and Completion of Upgrading Report, outlining research schedule for main research period (Abbot 1993)
- **September 1993 - October 1994** Main Research Period, Malawi: Fieldwork completed, inputting of data and preliminary analysis
- **November 1994 - February 1996** Analysis and thesis write-up.

Chapter 4

The use of participatory research techniques to assess community use of natural resources

Introduction

Participatory Rural Appraisal (PRA) is a family of approaches and methods that enable rural people to present, share and analyse their knowledge of life and conditions (FAO 1989). Participatory research is an interdisciplinary tool, relying on community interaction and indigenous knowledge (Poffenberger et al. 1992a & b). It has been used in a number of forestry studies (see Soussan and Gevers 1989, Inglis 1991, Poffenberger et al. 1992a & b). This study uses participatory research methods to investigate the range and use of non-timber forest products (NTFPs) harvested by people from Chembe, the largest enclave village.

Objectives

- to examine the broad patterns of use of NTFPs and their importance in subsistence strategies
- to contrast pattern of use of NTFPs by different sectors of the community
- to collect oral histories and testimony and examine local priorities and options for use of natural resources
- to design formal methods of empirical data collection based on the information gathered during PRA sessions (see Chapters 5-9).

Methods

A range of PRA methods ~~were~~ was chosen to obtain baseline and historical information regarding the use of NTFPs and their value to villagers. These included: discussion groups (regarding access to resources, historical changes in resource use), key informant interviews (detailing NTFP use), transect walks, resource mapping and ranking/scoring different woodland resources (FAO 1989). A typical PRA activity consisted of a group of up to ten informants, a facilitator and a local translator. Each session lasted approximately one hour.

During the three month pilot study, in excess of twenty PRA groups were held in the five villages. Additional PRA sessions were held regularly in Chembe throughout the fieldwork, utilising three facilitators and three village research assistants. Groups were selected to represent a range of different interests, including farmers, fishermen, women, children etc..

Wealth ranking (Grandin 1988) was used as a non-invasive, participatory method of estimating relative income. Wealth ranking sessions, using randomly selected households and various independent, key informants, were undertaken within Chembe and Msaka villages. Some of the criteria selected by local informants to classify households into wealth classes were: quality of the house, income generating activities, clothes, foods and schooling of the children. After completing wealth ranking with nine informants and 140 households, four wealth classes were defined: Class 1 being the richest and Class 4 the poorest. See Appendix 1 for the criteria used to rank households.

Appraisal of methods

Participatory research methods secured a rapid, baseline survey of patterns of subsistence and the use of NTFPs within Chembe village. Group discussions and brain-storming sessions enabled comprehensive lists of forest resources and their uses to be discerned. Transect walks through the village, gardens and woodland provided foci for discussion and an understanding of subsistence patterns. Key informants, such as older residents, enabled an historical perspective to be defined (Slim and Thompson 1993).

Clearly PRA is subject to the vagaries of peoples memories as it tends to rely on description, rather than direct observation, of how resources are used. This information must be interpreted with caution since people may not act as they imply, especially with regard to sensitive or illegal issues (e.g. hunting). Furthermore, the accuracy of historical information and that of resource use projected to other seasons is difficult to assess because of the selective nature of memory (Slim and Thompson 1993). However, the use of participant observation throughout the study, including focal group follows of villagers gathering forest resources (see Chapters 8 and 9), helped to substantiate oral testimony. Similarly, my systematic recording of the use of forest produce throughout the year verified and assisted the interpretation of seasonal calendars.

Discussion between facilitators and research assistants following PRA sessions enabled thorough interpretation of information gathered. Successive groups built on, verified and cross-checked information. I consider that the triangulation of methods enabled a reliable appraisal of subsistence patterns and resource use to be made. My extensive and protracted experience within the community helped to mitigate against some of the problems levelled against the uncritical use of PRA techniques *viz.* questions of representative data, village divisions and awareness of the personal agendas of individual informants. Every effort was made to incorporate and consult a full range of interested parties. Hence, I have confidence that the research provides a reliable reflection of resource use within Chembe.

While PRA defined a list of NTFPs, it was difficult to estimate the value of these items to villagers, in terms of income, diet or subsistence. The present study suggests that specific data quantifying the contribution NTFPs make to subsistence are not achievable with PRA methods. Systematic methods of data collection are required, to follow up and define more precisely dependence on forest products. Chapters 5 - 9 analyse empirical data collected to explore more thoroughly the issues raised during PRA sessions.

In this section, the principal aim was to define people's priorities and rank forest products in terms of their significance to the villagers. This was achievable in a relatively unintrusive and informal manner using PRA techniques. Furthermore, the techniques facilitated my relaxed introduction into the communities using techniques that were enjoyed by facilitators and participants alike. Overall, the techniques provided considerable baseline information regarding the use of both marketed and non-marketed NTFPs. Such material provides a focus for community extension efforts and initiates a forum for debate regarding options for sustainable resource use. Thus, opportunities may be developed for real, tangible benefits of protected areas to accrue to local people. This is the essence of sustainability and the concept of Joint Forest Management (JFM) schemes which enhance relations between resource managers and user groups (Poffenberger et al. 1992a & b).

Results

Table 1 displays the natural resources harvested from the *miombo* woodlands of LMNP. Table 2 details patterns of resource collection according to gender and age. More detailed descriptions of the patterns of use of NTFPs harvested from LMNP by people from Chembe village are found in Appendix 2. Furthermore Chapters 6 and 8 provide detailed analyses of resource harvesting with regard to gender and age respectively.

Table 1. Resources collected from miombo woodland.

Primary Products	Secondary Products
Firewood - domestic	Wild plant foods
Firewood - fish processing	Medicines
Building poles	Fibres and dyes
Grass	Bushmeat (mammals and birds)
	Insects
	Curios for tourist industry
	Domestic tools

Table 2. Patterns of Collection and Use of NTFPs.

Resource	Adult Male	Adult Female	Male Child	Female Child	D	I
Firewood - domestic	-	R	-	R	✓	✓
Firewood - fish processing	R	-	-	-	✓	✓
Building poles	N	-	-	-	✓	-
Grass	-	S	-	-	✓	✓
Wild plant foods	-	OS	RS	RS	✓	✓
Medicines	N	N	-	-	✓	-[1]
Fibres and dyes	N	-	-	-	✓	-
Bushmeat	O	-	O	-	✓	-
Insects	-	-	S	S	✓	✓
Curios for tourist industry	-	-	R	-	-	✓
Domestic tools	N	N	-	-	✓	-

[1] Medicines are sold by traditional doctors and traditional birth attendants only.

D domestic use and subsistence
I income generating activity
R regular collection
O opportunistic collection
S seasonal collection
N 'needs basis' collection
✓ NTFP used for this purpose

Discussion

The Discussion opens by defining terms for gathered natural resources and outlines the use (Table 1) and patterns of collection (Table 2) of NTFPs within LMNP. The main areas of focus are: patterns of collection and use of NTFPs by different sectors of the community, seasonality, food security and income generation. This discussion includes a description of the regulation of natural resources by the Malawi Department of National Parks and Wildlife (MDNPW) and local access to NTFPs from the Park woodlands. This chapter therefore establishes a framework for the detailed analysis of resource use presented in the subsequent chapters.

Definitions

While the term 'minor forest produce' is commonly found in the literature (e.g. Koppell 1990), it is not used in this thesis. Findings from PRA suggest that the term 'minor' does not depict accurately the use of forest products from LMNP. Some resources are used in 'minor' quantities or sporadically (e.g. medicines) but they appear to be of great significance to the welfare of local people. The importance of a resource also varies according to the sector of the community approached, and depends upon factors such as age and gender (Table 2). Thus, a resource should not be classified as 'minor' unless an assessment of its use within the whole community has been undertaken. The term non-timber forest products (NTFPs) is preferred and is used to describe natural resources gathered by Chembe villagers.

In this analysis, NTFPs collected from the *miombo* woodlands are classified into primary and secondary products on the basis of their importance to the villagers. PRA sessions consistently showed that a few forest products were ranked 'most important' because they were used regularly by each household in the village. These 'primary products' include firewood, building poles and grass for thatching and fencing. These resources are the major focus of this thesis. A wide range of other forest products show alternative use patterns. These 'secondary products' are: used on a needs basis (e.g. medicines), collected opportunistically, as they are encountered (e.g. wild fruits or insects), or, are utilised only by certain sectors of the community (e.g. ropes for fishermen and seeds for jewellery-making are collected by people working within the tourist sector). Table 1 categorises NTFPs into primary and secondary products. This classification is used throughout the discussion.

Patterns of Resource Collection

Tables 1 and 2 demonstrate the range of products that are gathered from the *miombo* woodland. Most resources show specific collection patterns, with regard to either gender or age. These reflect the traditional division of labour. For example, fishing is a predominantly male activity, hence the wood required for fish processing is collected by male adults. By contrast, cooking and other domestic activities are undertaken by women. Domestic fuelwood, as a prerequisite for cooking, is seen as a household requirement and its collection is therefore undertaken by women, assisted by elder daughters. Gender differences in patterns of fuelwood collection and the impact of resource collection on the local environment are explored in Chapter 6. The role daughters play in the household in assisting their mothers to collect domestic fuelwood is discussed in Chapter 8.

Seasonality in the use of NTFPs

During PRA discussions regarding household use of fuelwood, women claimed to use similar amounts of wood throughout the year. While further analysis of domestic fuelwood consumption is provided in Chapters 6 and 8, the results of household monitoring appear to confirm the women's assertions regarding their patterns of fuelwood use: Figure 3, Chapter 6 suggests there is no overall significant seasonal pattern in household use of fuelwood. The only exception is a peak in fuelwood use in the month of July. During this month, fuelwood consumption is significantly higher than during the month with lowest fuelwood consumption, November.

An explanation for this pattern of fuelwood use is provided by the women who assert that wood is used primarily for cooking and heating water. Fuelwood is only rarely used for space heating and thus there is very little fluctuation in fuelwood consumption throughout the year. Figure 1 shows the collated climatic data for Monkey Bay and demonstrates the equable local climate. It indicates that July has the lowest recorded temperature and is in the 'cold season'. A peak in fuelwood consumption in this month is attributed to the increased consumption of hot food and drinks and limited use of fires for heating only during this coldest month of the year. This may explain why significantly more wood is used in this month than in November which is in the 'hot season'. November has a much higher recorded temperature than July and during this hotter month (as for most months of the year) no space heating is required.

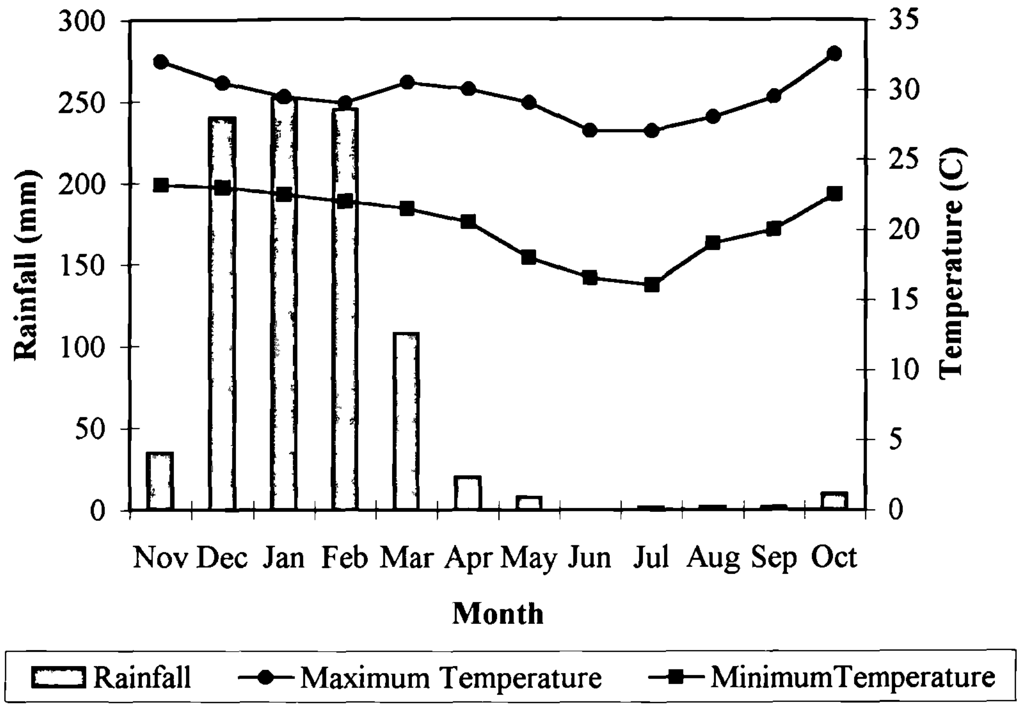


Figure 1. Collated climate data for Monkey Bay (1983 - 1990).
(Adapted from Nankumba Peninsula Strategic Plan, MFNR 1995).

Apart from fuelwood, other NTFPs show a more seasonal pattern of use, linked to their availability. This particularly applies to gathered wild foods, but also to grass, a primary resource, used for thatching and fencing, which is collected throughout the dry season. There is a long-standing debate between the MDNPW and the villagers regarding the cause of fires in the woodland. Fires early in the dry season preclude the harvest of grass thatch but may also prevent a more serious fire occurring later in the dry season. The impact of fire on the Park woodlands is discussed further in the next chapter.

In common with the findings of Fleuret (1979) and Campbell (1987), this study found that children play an important role in the collection of seasonally available wild foods. They are the only sector of the community that make specific collection trips to the woodland, often in a group after school, to gather insects or wild fruits, when they are in season. Phenological studies suggest that fruiting for *miombo* species occurs mainly during the main and late rainy seasons (Malaisse 1974). Consistent with the findings of an early nutrition study in Malawi (see Berry and Petty 1992 p.27), this study found that wild fruits and insects tend to be eaten between meals as snacks. The nutritional importance of such foods is well documented in the literature (Carr 1958, Gura 1986, Kalenga Saka et al. 1992, Berry and Petty 1992).

Food security and NTFP use in Chembe

Historically, edible NTFPs were used more frequently during both seasonal food uncertainty (the annual hungry season, first postulated by Platt 1954, cited in de Garine and Koppert 1990) and hardship periods (e.g. droughts and crop failure). Particularly important were substitute staple foods, such as roots and wild grasses. Currently, a few edible NTFPs are utilised to a greater extent during periods of food stress, including: the root of *Euphorbia* spp., wild rice and some fruits. Generally, however, people in Chembe now find alternative income generating activities, rather than wild foods, to cope with periods of food stress.

Fishing and tourism are important village activities during these times. In effect, these two industries provide a safety net or buffer against serious hardship during droughts or seasonal hunger. NTFPs still have a role to play, however. Selling wild fruits (especially *Adansonia digitata*) and firewood were mentioned as coping strategies, to obtain money to buy maize during periods of food scarcity. Tree seeds are also required for making jewellery to sell to tourists. This income generating activity, undertaken by male children, contributes to many Chembe families. It is undertaken by boys because they are more likely than girls to attend primary school and thus have better English to converse with tourists (see Abbot 1995).

NTFPs and income generation

Table 2 demonstrates that many of the NTFPs collected for retail purposes are harvested by women and children. The economic activities pursued by women is discussed further in Chapter 7. However, wealth ranking within Chembe demonstrates that the collection and sale of grass and fuelwood is undertaken by the poorest sectors of the community. Indeed, the selling of these two resources was used as a criterion by informants to define the poorest households in Chembe during wealth ranking sessions (Appendix 1). This finding is consistent with those of other authors (see Godoy and Bawa 1993), documenting that NTFPs are more important among poorer households.

Figure 2 summarises patterns of NTFP collection and use, for both subsistence and income generation. NTFPs are sold at either of the two markets in Chembe, or informally, outside houses. The flowchart shows the internal nature of NTFP collection, use and retail within Chembe. The only resources leaving the system are traditional medicines and the seeds and wood used in jewellery making and carvings. The turnover in tourists provides a continuous market for locally made curios, sold primarily by village children. Few NTFPs are sold at markets outside the village, not even at the local town of Monkey Bay although NTFPs from other areas are regularly traded there. The potential for communities living within the National Park to market NTFPs is explored in Chapter 7.

Figure 3 details fuelwood collection and retail within Chembe village. While fuelwood is not traded outside the village, there are a range of internal markets for this resource. Only men collect fuelwood for use in fish smoking. While the fuelwood does not leave the village, the product, smoked fish, is taken for sale to inland towns such as Dedza, Ntcheu, Blantyre and Lilongwe. In this way, an important commercial venture (fish processing), accessing markets outside of Chembe, is dependent on fuelwood gathered from the Park woodlands.

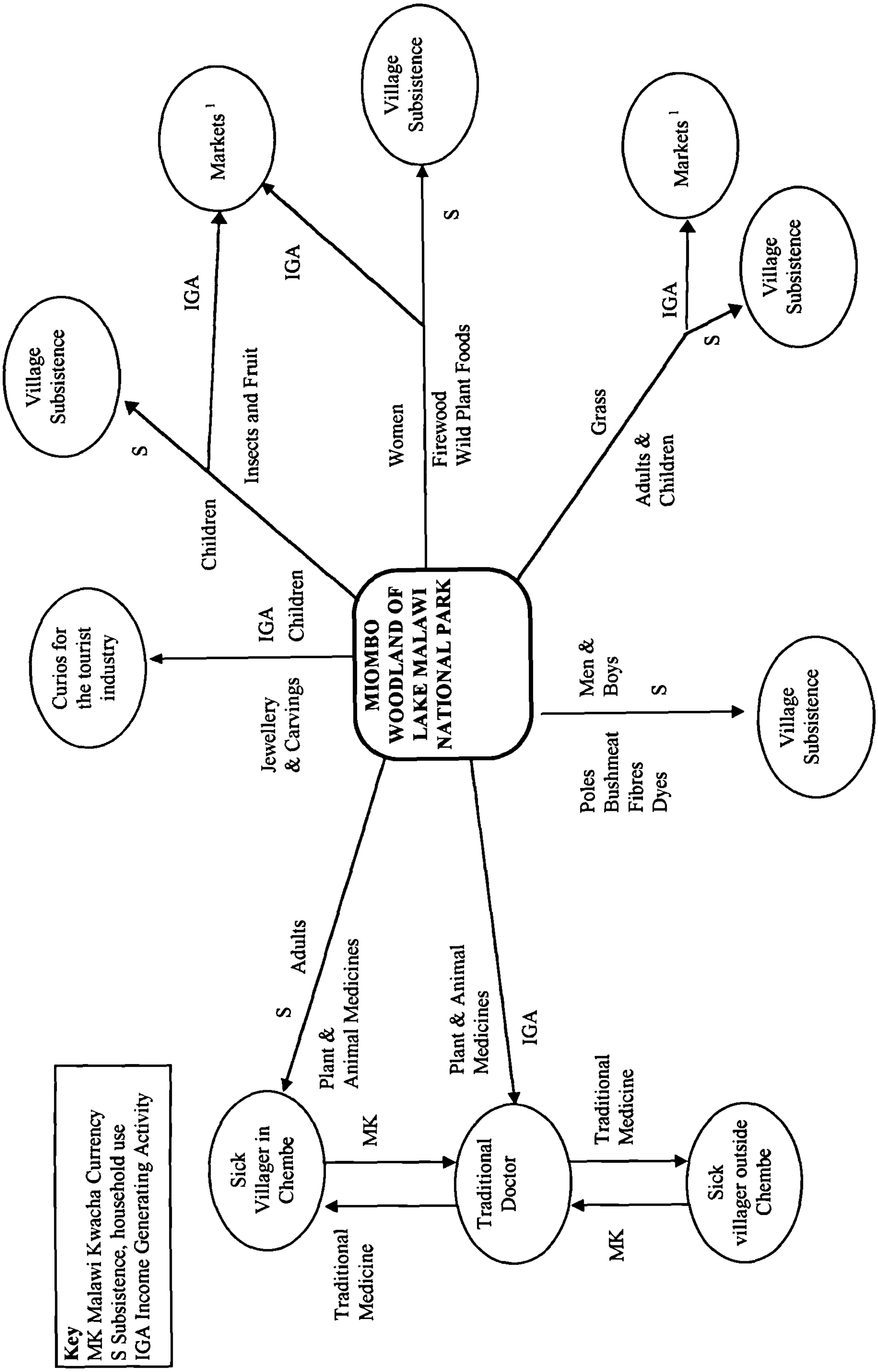


Figure 2. A Summary of Patterns of Harvesting and Use of Non-timber Forest Products within Chembe.

[1] All markets are internal. NTFPs leave Chembe village only through the tourist industry and services of the traditional doctor.

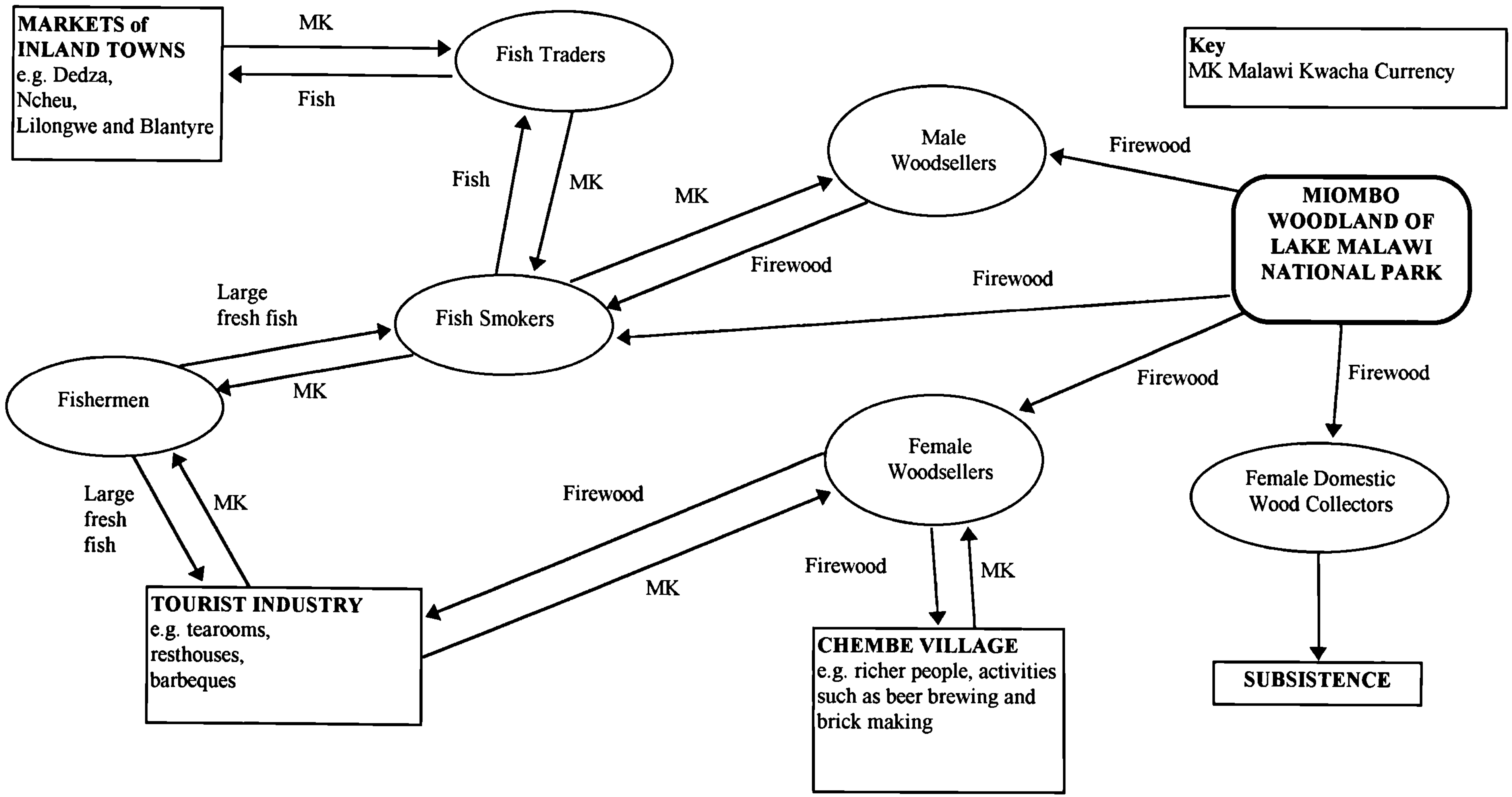


Figure 3. The links between fuelwood and commercial and subsistence activities in Chembe village.

Generally, women collect firewood for domestic consumption. Chapter 6 contrasts the ecological impact of the different patterns of wood collection associated with domestic and commercial activities. Wood collected by women for retail is used predominantly in the tourist service industries. Fuelwood collection is an important income generating activity among women from Chembe, because it offers them an independent source of income. Moreover, Barrett and Browne (1995) suggest that trade in natural resources, such as fuelwood, is important for women because the 'free' goods harvested from the environment are 'a means by which rural women can survive, despite limited access to land or capital resources'.

Access to resources and the history of NTFP use

First restrictions on local access to the woodland were placed in 1948, when the Nankumba peninsula was gazetted a Forest Reserve. Older people remember the cessation of maize cultivation on the wooded hill slopes and islands. However, further restrictions and village complaints regarding access to the woodland stem from the conversion of the Forest Reserve to a National Park in 1980. The prevention of agricultural encroachment into the woodland was enforced and a ticket system for dead wood collection introduced (see Chapter 2).

In theory, the collection of all other NTFPs is illegal, although the recent National Parks and Wildlife Act (1992) makes provision for appropriate, controlled harvesting of defined resources within protected areas. However in practice, and as demonstrated by this research, villagers are utilising a wide range of forest products. Regulated woodland access is vital for both subsistence and trading activities based on NTFPs. Natural resources, such as firewood, are critical for economic activities undertaken primarily by women (especially female headed households) from the poorest households in Chembe. It is these vulnerable sectors of the community that are most dependent on the Park woodlands.

Conclusions

This study has enumerated the range of NTFPs used by Chembe villagers and highlights local dependence on the *miombo* woodland habitat. Fuelwood and construction materials (building poles and thatching) are the major, primary products that are harvested. A wide range of secondary products are utilised including: edible plant foods, bushmeat, insects, fibres and dyes, medicines, wood for making domestic utensils and seeds and hardwoods for making curios for the tourist industry.

Clearly, primary and secondary products play an important role in both subsistence strategies and provide opportunities for income generation within Chembe, especially for the poorest sectors of the community. Given the isolation of the enclave villages, it seems likely that the woodlands will continue to be an important resource for villagers in the future. However the problem of a large population dependent on a limited resource base remains. The variety of NTFPs that are used requires conservation of the diverse *miombo* community. Thus, conservation strategies should be designed in conjunction with local communities to ensure equitable woodland access and sustainable use of its resources. The variety of species that comprise NTFPs suggests that woodlots are not an adequate substitute for *miombo* woodland. Local people require access to the Park for harvesting NTFPs other than building poles and fuelwood. However, the establishment of woodlots could reduce dependence on the woodland and conserve the *miombo* resource base as a source of other NTFPs, such as wild fruits and medicines.

Because many NTFPs are not marketed, or are sold only within an internal system, the importance of *miombo* woodland to the villagers, for both income and subsistence, may not be apparent to Park managers. Future, more informed policies for resource collection and use should aim to:

- recognise the importance of the woodlands to the villagers, not just as a source of firewood, but for wide range of natural resources vital for local subsistence and income generation

- acknowledge that with high populations and high local demand for NTFPs, access to the Park's resources must be regulated to ensure both sustainable utilisation of NTFPs and conservation of the *miombo* woodlands
- understand cultural, age, gender and wealth differences in resource collection and use, such that informed access strategies are developed. All sectors of the community should be consulted, including traditionally under-represented groups (such as women and the poor) who appear from this analysis to have the most to gain from NTFP utilisation.

This chapter has provided an overview of patterns of use of NTFPs and their general contribution to subsistence strategies. The following chapters explore the local use of NTFPs, particularly primary resources, in more detail and contrast the impact of different harvesting practices on the *miombo* resource base.

Chapter 5

The floristic composition of the woodlands of Lake Malawi National Park.

Summary

This chapter describes the woodlands of Lake Malawi National Park (LMNP). It assesses the importance of different environmental variables in explaining the floristic composition of the woodland vegetation. The quadrat-based woodland survey provides a static portrait of the vegetation but patterns of land-use may be inferred from the floristic composition of sample sites. The findings are discussed with regard to the management of the Park to meet the dual aims of protecting watersheds and enabling local communities to harvest woodland products.

Introduction

The three broad categories of woodland vegetation that dominate the Zambezian Region of Southern Africa are mapped and described by White (1981, 1983). They comprise *miombo, mopane* and undifferentiated Zambezian woodland. Other woodland types, including scrub, riparian, *chipya* and wooded grasslands, fall within these broad categories and are described, but not mapped separately, by White (1983). Using White's (1981, 1983) vegetation classification, LMNP falls within an area of undifferentiated Zambezian woodland. The dominants of *miombo* are usually absent from undifferentiated woodland (White 1983). Their presence within LMNP (see below) suggests that the vegetation is more similar to the *miombo* woodlands that dominate the rest of Malawi, although the woodlands also contain elements from both *chipya* and scrub woodland. Furthermore, in his vegetation map of Malawi, Jackson (1968, 1969) classifies the Nankumba Area as *Brachystegia* woodlands and scrubs, intermixed with escarpment and lakeshore woodlands.

Miombo woodland occurs on the fine-textured, infertile soils, typical of the ancient Miocene landscape of the central African plateau. These soils have a low cation exchange capacity and low organic matter content. The main *miombo* trees and shrubs have deep root systems, that descend to a depth of approximately 5 metres to tap the moisture retaining layers of the soil during the dry season. Root profiles drawn by Timberlake and Calvert (1993) demonstrate the massive storage root systems of the *miombo* canopy dominants.

Miombo is characterised by a light, single storey but closed canopy, attaining a height of approximately 12 - 15 metres (Lawton 1982). As outlined in Chapter 2, it is usually dominated by tree species from the genera *Brachystegia* and *Julbernardia*. These belong to the Cassia subfamily (Caesalpinioideae) of the Leguminosae. The shape of the canopy dominants give *miombo* a distinctive appearance. The boles are mainly short and the branches spread out to support a shallow, flat-topped crown bearing pinnate leaves (White 1983). *Miombo* woodland is often interspersed with evergreen to semi-evergreen forest types and shows considerable variation in structure and composition (see below). An overview of the *miombo* ecosystem is provided by Malaisse (1978) and White (1983).

Miombo Succession, Regeneration and Land-use

Miombo is not generally considered a climatic climax, but a fire climax (Malaisse 1978). Chidumayo (1988c) describes *miombo* as a kind of climax vegetation, whose 'maintenance is often reinforced by fire and other anthropogenic disturbances'. The use of the term 'climax' vegetation in this context may be challenged due to the dynamic nature of the ecological relationships that maintain *miombo* (Lawton 1978 and pers. comm.). Many authors would now distinguish between equilibrium and non-equilibrium systems and view savannas as dynamic mosaics undergoing continuous shifts between alternative states (see Behnke & Scoones 1993). The appropriate ecological model may be determined using a functional classification of savanna types based on various permutations of available soil moisture and soil nutrients (see Frost et al. 1986 in Behnke & Scoones 1993). Within this classification, it appears that conventional successional interpretations are more valid in African *miombo* than in areas where rainfall is both low and erratic (e.g. the Sahel). Thus, to the extent that vegetation formations can still be considered in terms of succession to a recognisable climax, the climatic climax of *miombo* is attributed to a scarce, dense dry forest, known variously as *muhulu* or *mateshi*. Cutting, cultivation and burning transform this into *miombo*. Hence the common classification recognises three stages in the succession: dense, dry forest - open woodland - savanna. This is often called the *muhulu-miombo*-savanna regression (Malaisse 1978).

Fire is important in maintaining, and determining the extent of, vegetation communities. Huston (1994) notes the role of fire 'for maintaining the populations of certain species, for increasing overall species diversity, and for preserving landscape pattern'. Water availability is a prime factor determining the frequency and intensity of fire (Stott 1991, Huston 1994). The alternation of wet and dry seasons in sub-tropical Africa provides ideal conditions for fire: Huston (1994) suggests that 'fire is a prominent and largely inevitable landscape-scale process wherever a dry season predictably follows the growing season'. There is a strong inverse correlation between the frequency and intensity of fires (see below).

A natural fire regime appears to have been responsible for influencing the floristic composition and distribution of plant communities long before the advent of anthropogenic fires (Manry and Knight 1986). In Africa, lightning is recognised as the most important natural cause of fire in vegetation. However, only a small fraction of lightning ground strikes result in vegetation ignition because fire requires a source of combustible plant matter. Manry and Knight (1986) suggest that lightning induced fires occur less frequently today than in pre-modern times. They attribute this to the heavy utilisation of most vegetation types which reduces fuel loads. Furthermore, the spread and intensity of fires is reduced by man-made features (such as roads) that act as fire breaks and controlled burning which exclude extensive areas that would otherwise be subject to lightning-induced fires. Thus anthropogenic fires, which can either be intentional or accidental, are likely to be more important than natural fires in determining the extent and floristic composition of vegetation.

Deliberate burning is often part of the shifting cultivation systems within tropical Africa. The effects of fire and shifting cultivation patterns on the floristic composition of *miombo* woodland have been well documented, particularly within Zambia (Boaler and Sciwale 1966, Strang 1974, Lawton 1978, Kikula 1986, Stromgaard 1985a, 1986b and 1992, Chidumayo 1987b, 1988b and 1993). Such controlled burning contrasts with bush fires (also deliberately started), which facilitate hunting, pasture management and clearance of tsetse flies from settlement areas (Lawton 1982, Kikula 1986, Stromgaard 1992).

Shifting cultivation is not undertaken in LMNP. The settled agriculture which used to be practised on the lower, wooded hill slopes prior to the establishment of the national park has been discontinued. However, there are many fires in the woodland throughout the dry season. The cause of these fires has been difficult to establish, being attributed to both villagers and scouts from the Malawi Department of National Parks and Wildlife (MDNPW). There is no official burning policy in LMNP, although an early burning regime is implemented at another *miombo* protected area in Malawi: Kasungu National Park. Some woodland fires at LMNP appear to be accidental in that fires used to clear farm plots may spread to the protected area. This is especially common where agricultural land lies immediately adjacent to the Park boundary. However, villagers living close to the woodland may deliberately burn grass, in woodland areas proximate to the village, early in the dry season (Bootsma 1987). Villagers also blame Park scouts for early fires within the woodland. While early burning prevents a serious late fire, it destroys the grass layer and prevents a harvest of thatch. This primary resource is an important local construction material, used for roofing houses and building fences (see Chapter 4 and Cunningham 1993).

Whatever their cause, intense dry-season fires are a characteristic feature of *miombo*. The timing of fires is a major problem in managing regeneration in the savanna woodlands of tropical Africa. In a classic study, Trapnell (1959) reviewed the ecological results of burning experiments undertaken within the *miombo* woodlands of Ndola, Northern Rhodesia[1] during the period 1933 to 1956. He demonstrated the drastic effects of late burning on young regeneration, the total stocking of the small tree and shrub layer and, most notably, on regeneration of the canopy dominants. He suggested that woodland can be destroyed by late burning. However, complete protection from fire not only increases the risk of fire due to accumulation of ground fuels, but may also result in a lowering of

[1] Now Zambia

species diversity, through the loss of a large number of understorey species in the coppice (Chidumayo 1988b).

Woodland regenerates when grass is burnt during the cool season because the trees and shrubs are dormant. Such early burning treatments are favoured because they maintain regeneration, and mitigate against the effects of a serious, accidental fire (Lawton 1982). Grass burnt during the hot season, when the trees and shrubs have flushed, reduces the regrowth to an open type of vegetation, dominated by fire-hardy trees and shrubs, known as *chipya* (Trapnell 1959, Lawton 1978 and 1982). Lawton (1964) describes *chipya* as a group of tall trees set in a matrix of understorey trees, with a dense, highly inflammable herb and grass layer. The creation of a light, patchy canopy in such woodland controls the intensity of grass fires, and creates favourable conditions for the regeneration of *miombo* canopy tree species, (Lawton 1978).

Fire-sensitive *miombo* canopy dominants (*Brachystegia* and *Julbernardia*) are unable to regenerate directly after fire or abandonment of cultivation plots (Boaler and Sciwale 1966, Lawton 1978, Kikula 1986). Following disturbance, regeneration occurs mainly through suffrutices i.e. vegetative reproduction known as 'coppicing' from existing tree stumps and root masses. Fire hardy and shade intolerant *chipya* species thrive under the harsh conditions and grow rapidly, such that a patchy canopy forms and closes over within 10 - 20 years. Under their protection (and often under species of *Uapaca* and *Bauhinia*), fire sensitive *miombo* and *mateshi* species are able to regenerate. The *Uapaca* coppice suppresses tall grasses and so eliminates fires. The lateral, open network of roots (Timberlake and Calvert 1993) provides a favourable habitat for the regeneration of the *miombo* canopy species.

Differences in the rate of growth of *chipya* and *miombo* species are apparent during, and important for, *miombo* regeneration (Boaler and Sciwale 1966). Shade intolerant *chipya* species, such as *Terminalia sericea, Pericopsis angolensis, Pseudolachnostylis maprouneifolia* and *Diplorhynchus condylocarpon*, are fast growing in the early stages of regeneration and are the pioneers of *miombo* regeneration. Typical, *miombo* canopy dominants are not conspicuous at this stage because they grow more slowly and are less resistant to fire. Indeed, Boaler and Sciwale (1966) postulate that the intensity of fires in the early years after disturbance slows their growth. However, as regrowth proceeds the growth of species typical of the understorey declines, while the slower growing *miombo* dominants continue to grow and achieve canopy status. Ultimately, pioneer species may either disappear or be maintained as understorey species under a mature *miombo* canopy.

While generally accepted and consolidated by a number of studies in different geographic locations (e.g. Trapnell 1959, Kikula 1986), this successional pattern is challenged by Stromgaard (1986b). In his study area in Zambia, two vegetation types were dominant: *miombo* and Combretum savanna. He examined a time series of abandoned shifting cultivators plots and found that the canopy that developed, even twenty five years after burning, did not include the dominant *miombo* species. The absence of *Brachystegia* and *Julbernardia* spp. and the presence of species characteristic of *Combretum* savanna, lead him to suggest that 'the recovery of the dominant canopy species of woody *miombo* is by no means rapid or assured via succession during the first 25 yr following site abandonment'. He attributes this to the transient presence of fire resistant *chipya* species in the early stages after site abandonment which prevented *Uapaca* spp. and *miombo* dominants from re-establishing themselves. This study corroborates the discussion outlined previously that the term 'climax' may be inappropriate for *miombo* woodland and that 'a dynamism in the successional processes' (Stromgaard 1986b) determines local floristic composition.

Floristic Composition

Several studies describe species associations within *miombo* (see Werger and Coetzee 1978). The most detailed phytosociological surveys of *miombo* vegetation have been carried out in Shaba (Katanga), the Copper Belt region of Zaïre. These classified the *miombo* communities into four alliances, which together make up the order *Julbernardio-Brachystegietalia spiciformis*. This order comprises most of the woodlands dominated by Caesalpiniaceae in Angola, Zaïre, Zambia, Malawi, Moçambique and Zimbabwe (Werger and Coetzee 1978).

A few studies have classified *miombo* vegetation using a range of ordination techniques. In an early classification of *miombo* from Tanzania, Boaler (1966) used association analysis to group sample quadrats into classes on the basis of their floristic composition. Numerical classification methods have been developed since that improve on this presence/absence enumeration of species at each site (see Kent and Coker 1992). However, Boaler found his groups represented 'a catena or continuum of vegetation, rather than separate floristic entities'. Lawton (1978) used a principal components analysis (PCA) to ordinate 398 stands. A majority of these stands were found to be of intermediate floristic composition, with no discrete associations. Similar to Boaler (1966), he interpreted the vegetation as a continuum, reflecting the complex history of each site *viz.* physical factors (such as topography, climate, soils and natural fires) and human influences (including fire, cultivation practices, charcoal making activities etc.).

Specific Objectives

A combination of abiotic and biotic variables, particularly anthropogenic factors, appear to influence the floristic composition of *miombo* woodland at a given site. Thus, this study explores the floristic composition of sample sites to determine whether:

- there are different associations of species at sample sites
- species associations can be related to various ecological variables
- species associations can be related to woodland utilisation by local communities.

Methods

A vegetation survey of LMNP was undertaken from February to June 1994. The woodland was surveyed systematically using a quadrat-based sampling method (Mueller-Dombois and Ellenberg 1974, Goldsmith et al. 1986, Kent and Coker 1992). The survey was undertaken with assistance from an officer and two research scouts from the Malawi Department of National Parks and Wildlife (MDNPW) and a local enumerator. All four were proficient in tree identification. Additional support was provided by an expert from the National Herbarium and Botanical Gardens of Malawi (NHBGM). Binns (1972), Pullinger and Kitchin (1982), Coates Palgrave (1983) and Shorter (1989) were used for tree identification but nomenclature follows Coates Palgrave (1983).

Sampling method

A stratified random sampling method ensures an even distribution of sampling effort across different vegetation zones. Aerial photographic analysis provides a useful method of stratifying vegetation (see Chapter 6). Unfortunately, the aerial photographic analysis was not completed before the vegetation survey was undertaken (January - May 1994). In the absence of a sampling frame, the quadrats were distributed randomly. A grid of co-ordinates was used for sampling. From each co-ordinate, sample stands were located using a random walk procedure: compass bearings and the number of paces to be walked were selected using a random numbers table (Kent and Coker 1992).

Enumeration data

Within each quadrat, all trees above 1 metre in height were enumerated. Each tree was identified and its position in the woodland stratification was noted: i.e. canopy, understorey, or shrub. Where field identification of trees proved difficult, samples were collected and pressed, for later identification at the NHBGM. The position of each quadrat was recorded on a 1:50 000 map. Contours lines and spot heights were used to estimate the altitude of each quadrat. Average slope was measured using a Suunto clinometer and calculated from three separate readings for each quadrat. Other measures for each quadrat included: position of each quadrat on the slope, canopy cover and relative accessibility. Data for these parameters are ordinal, because each quadrat was placed in rank order along a continuum or scale (Kent and Coker 1992).

The position of each quadrat on the slope was recorded on the following scale:

1 – *Dambo*, or seasonally wet flood plain   2 = Lower slope

3 = Mid-slope   4 = Upper slope.

Canopy cover was similarly assessed along a scale, such that:

1 = No canopy cover   2 = Adjacent tree crowns don't meet

3 = Adjacent crowns meet   4 = Crowns overlap, allowing light penetration.

Finally, each quadrat was assessed for its accessibility, the time it would take to walk to the quadrat from the nearest village. This is an index combining two measures: the altitude of the quadrat and its horizontal distance from the nearest village on the same face of the hill. The index is adapted from Naismith's Rule for route-planning (Birkett 1993) and includes estimates of walking speed and ascent rates. Travel time to a quadrat was calculated by assuming: a person walks at a speed of 4.8 km per hour on flat terrain and that an additional hour is required to ascend every 500 metres. While individual fitness affects walking pace and the nature of the terrain affects individuals differently, the purpose of this index is not to measure exact travel times to each quadrat. Rather, it is a measure of the relative accessibility of each quadrat for villagers. Travel times to each quadrat were converted to an Index of Relative Accessibility, according to the following scale:

1 = < 0.5 hr   2 = $\geq 0.5 < 1.0$ hr

3 = $\geq 1.0 < 1.5$ hr   4 = $\geq 1.5 < 2.0$ hr.

System notes, including indicators of past history or management, were made for each quadrat. For example, where ridges and furrows could be seen within a quadrat, this was recorded as indicative of cultivation in the past. Fire posed a difficult problem. Although it is an important feature of *miombo*, LMNP has no policy on burning and undertakes no management burning. Village informants were also unable to reconstruct local burning patterns because throughout the dry season, they start many small and localised fires (in addition to the accidental fires, outlined previously). The non-systematic burning patterns mean reliable evidence of the fire history of each quadrat is not available. It proved impossible, therefore, to identify sampling areas which had been burnt or excluded from burning. The recent burning history of sample sites could be ascertained only if direct evidence of fires (for example, charred stumps) was encountered.

Quadrat size

The size of the quadrat is an important feature of vegetation surveying. Optimal quadrat size is estimated using the minimal area concept. Minimal area is defined as the smallest area on which the species composition of the community is adequately represented (Mueller-Dombois and Ellenberg 1974). Using the nested plot technique, species-area curves may be drawn. As sample area increases, fewer additional species are encountered and the curve levels off. Optimal quadrat size should be larger than the point of inflection of the curve, and contain at least 90 or 95 percent of the species encountered (Mueller-Dombois and Ellenberg 1974).

To estimate minimal area successfully, the sample stand should be selected to meet the following conditions:

- it should be large enough to contain all the species belonging to that community
- the habitat should be uniform within the stand area
- the plant cover should be homogeneous.

In this study, quadrat size was increased regularly from 1 m^2 to 900 m^2 and the cumulative number of species was plotted against quadrat size. Three nested plots were undertaken within LMNP: two within closed canopy woodland (Figure 1) and one in sparse woodland (Figure 2). The two species-area curves undertaken in closed canopy woodland show similar patterns with the species curve levelling off at approximately 600 m^2 (Figure 1). The appropriate quadrat should be of a size slightly larger than this minimal area (Kent and Coker 1992).

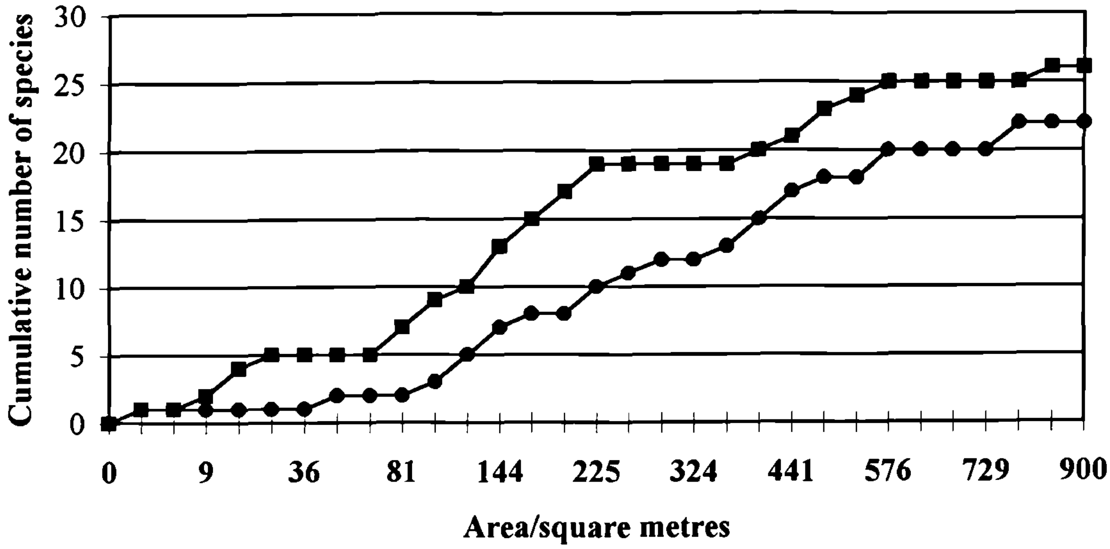


Figure 1. Repeated species-area curves undertaken in closed canopy woodland.

Figure 2, the nested quadrat undertaken in sparse woodland, shows a different pattern. The number of species levels off at small quadrat size (approximately 200 m^2), but then slowly increases again. Kent and Coker (1992) note that where sample stands are not uniform, the minimal area curve may rise again after levelling. This is because as the sample area increases, different communities or an ecotone between community types may be sampled. Figure 2 suggests that sparse woodland is not a uniform vegetation type and contains more than one plant community. The species-area curve represents gamma diversity i.e. species richness across several communities within one landscape unit (Whitmore 1990). It therefore deviates from the conditions required for calculating minimal area, as outlined above.

This demonstrates that while minimal area is a useful concept, in practice it is difficult to define (Kent and Coker 1992). Where the species-area curve fails to level off as anticipated, a compromise must be made. A sample size should be chosen that is practical and manageable, even if it contains only a fraction of the number of species of the community type (Mueller-Dombois and Ellenberg 1974). However, the same size quadrat should be used throughout a survey to enable different community types to be compared directly (Kent and Coker 1992).

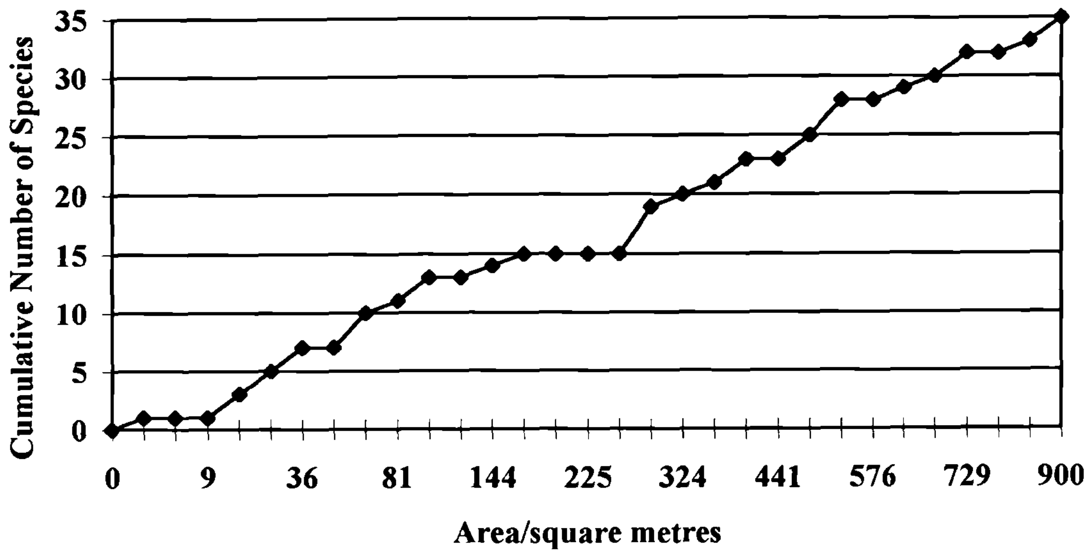


Figure 2. Species-area curve for sparse woodland.

To circumvent the problem of differences in vegetation pattern (i.e. the spatial arrangement of individuals within a plant community), the largest size quadrat to suit all species within a survey should be chosen (Kent and Coker 1992). To this end, a quadrat size of 900m^2 was chosen as appropriate for this woodland survey, to account for the heterogeneity of sparse woodland communities. To minimise edge effects (Goldsmith et al. 1986), a square, rather than oblong, quadrat of 30m x 30m was used. This quadrat size compares favourably with Mkanda's (nd) estimates of 'relevant woodland plot sizes' for Malawian *miombo*. Based on repeated nested plots within Kasungu National Park, he suggested plot sizes of either 900m^2 or 1600m^2.

Sample size

Sample size, in relation to vegetation surveys, is defined by Mueller-Dombois and Ellenberg (1974) as the number of times a quadrat should be repeated. They note that this is often arbitrarily delimited. Goldsmith et al. (1986) note that the number of sampling units depends on the variability between samples: no absolute sampling intensity can be suggested, and researchers should, therefore, adopt the general rule 'the more the better', within the constraints of labour and time involved. Alternatively, a sampling intensity may be pre-set, defining the percentage of the vegetation that should be sampled. World Bank (1991) note that, to obtain a precision of more than 15 per cent frequently requires a sampling intensity of 0.05 - 0.5 per cent of the area to be studied. In this survey, forty eight, 900 m^2 quadrats were completed, in a Park of size 87 km^2, giving a sampling intensity of 0.05 per cent. That this is sufficient sampling intensity is corroborated by species-quadrat number curve. Figure 3 represents the minimal area concept applied to sampling intensity. It shows the cumulative number of species plotted against quadrat number. The species-area curve levels off after about thirty five quadrats as few additional species are encountered. This suggests that sampling intensity was sufficient to incorporate the most commonly found species.

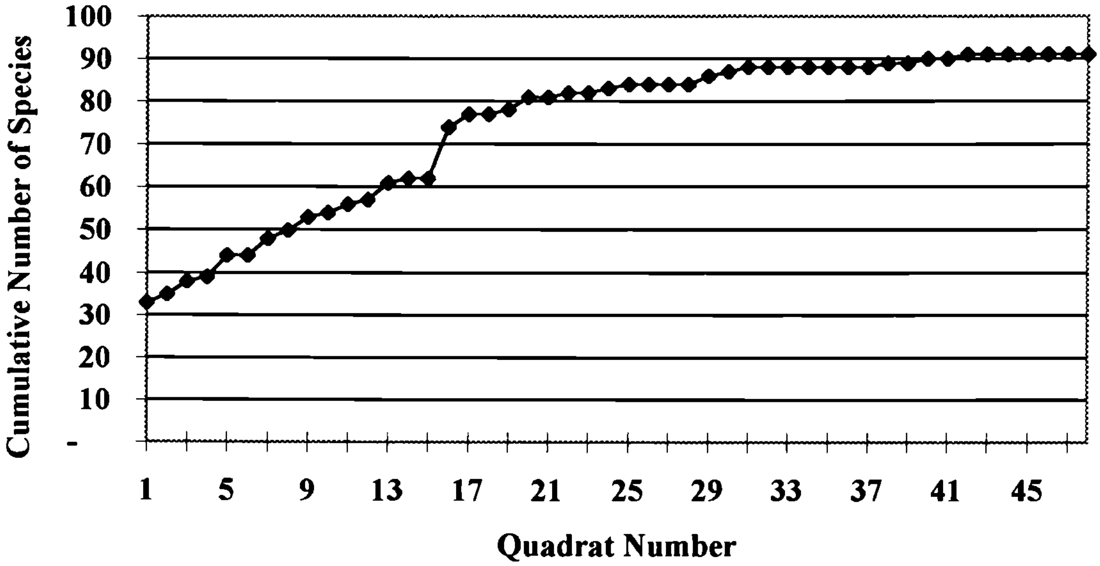


Figure 3. Cumulative number of species encountered during the vegetation enumeration.

Mueller-Dombois and Ellenberg (1974) and Goldsmith et al. (1986) recommend that the cumulative or running mean should be used to estimate the adequacy of sample size. The minimum number of quadrats is the point at which oscillations damp down. Figure 4 is a plot of the running mean of the number of species per quadrat plotted against quadrat number. It shows that sampling was of sufficient intensity because after approximately twenty five quadrats, additional samples do not significantly affect the mean.

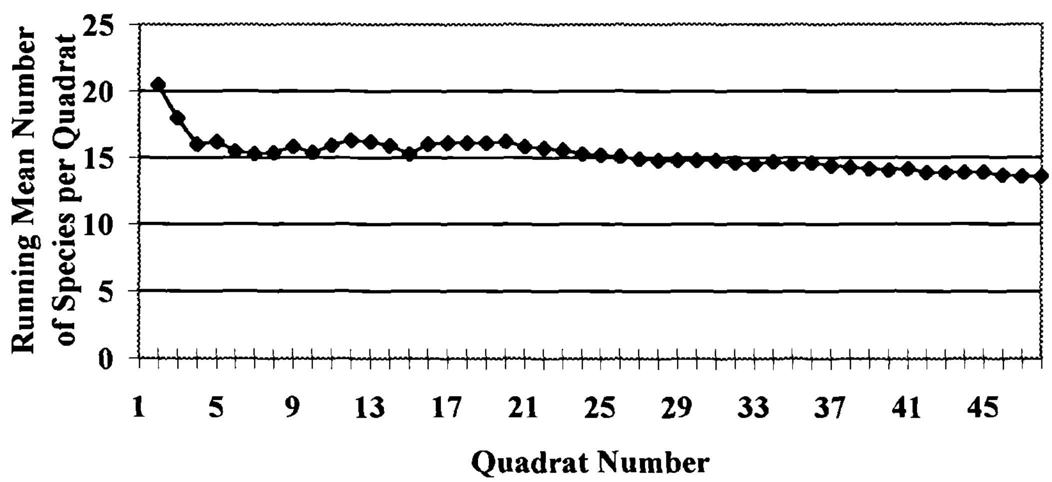


Figure 4. Running mean number of species per quadrat.

Data Analyses

The vegetation survey generated a complex data set of species, quadrats and various environmental variables. The multivariate nature of such data can make analysis, and the identification of pattern, difficult. However, a range of data reduction techniques (for example, classification and ordination) were used, which have been designed specifically for analysing complex ecological data. Unlike classical multivariate statistics, these techniques assume a unimodal, rather than linear, relationship between species and environmental variables. This provides a better representation of ecological distribution.

Such techniques have been used extensively in Europe to examine vegetation composition, the impact of ecological variables on floristic variation and, particularly, to reconstruct past land-use patterns (Wassen et al. 1990, Gaillard et al. 1992, 1994). Their use in Africa has been more limited, although Shackleton (1993) used classification and indirect ordination techniques to analyse species composition in response to fuelwood harvesting in the eastern Transvaal Lowveld.

The techniques require the vegetation data to be sorted, quadrat (sample or stand) by species, in a database. This raw data matrix, together with another, containing environmental parameters by sample, is used to explore the data for association and help generate hypotheses as to floristic composition. Thus, the techniques that are used in this chapter are methods of exploratory data analysis. In this study, the raw data matrix was compiled using the quantitative density values for each species in each quadrat. The multivariate analyses which were performed on this matrix are outlined below.

• A numerical classification of stands and species was undertaken using the computer program TWINSPAN (TWo way INdicator SPecies ANalysis, Hill et al.. 1975, Hill 1979b). TWINSPAN is a hierarchical technique for displaying the similarity and dissimilarity between vegetation stands. It is a divisive, polythetic classification technique that uses 'pseudospecies', the abundance of different species at pre-determined levels, to subdivide the data matrix into successively smaller groups. This provides a joint or two-way classification of quadrats and species.

- An indirect ordination using detrended correspondence analysis (DCA) was carried out using DECORANA (Hill 1979a) implemented through the CANOCO computer program (ter Braak 1986, 1987). An indirect ordination is a method of gradient analysis that arranges samples spatially such that their position reflects their similarity (Goldsmith et al. 1986). Biplots were produced by ordinating species and stands together using the program CanoDraw (Smilauer 1992) that supplements CANOCO. Subsequently, plots of the environmental data were superimposed on the quadrat ordination to assist hypothesis generation regarding floristic composition.
- A direct ordination was carried out, using canonical correspondence analysis (CCA) implemented through the CANOCO computer program (ter Braak 1986, 1987). This provided an ordination that is a product of variation in both floristic composition and environmental factors. This allows a direct interpretation of sample or species variation with reference to external environmental controls.
- Partial CCA is used to undertake a 'partial' analysis of species-environmental relationships i.e. to control for, or eliminate, certain environmental parameters from the ordination. This reveals the percentage of variation in the data that is explained by each environmental factor. Partial CCA was implemented through the CANOCO computer programme (ter Braak 1987).
- Monte Carlo Permutation Testing (a resampling procedure) involves the use of simulation to gauge the effects of random variables on ecological systems. The technique is used in association with CCA to test the significance of each environmental variable to the species-sample relationship. It was also used with partial CCA to test the significance of the residual effects of specific environmental factors, once co-variables had been removed. Monte Carlo Permutation Testing was implemented through the CANOCO computer programme (ter Braak 1987).

Results

Two Way Indicator Species Analysis

The complete two-way table produced by the TWINSPAN analysis is shown in Appendix 4. The 48 quadrats are listed across the top of the table, and the species codes are recorded in the left column. Appendix 3 contains the species names corresponding to each of the species codes. Most species have a distribution across many of the quadrats, and the program splits species, at the pseudospecies level, where they show a marked or disjunct clustering. The TWINSPAN program repeatedly subdivides the sample and species groups producing dendrograms for sample and species classifications (Figures 5 and 6 respectively). Interpretation of this output is partially subjective as the level of subdivision which makes best ecological sense should be used for classification.

The first stands division split one quadrat, characterised by the species *Albizia harveyi*, from the rest (Quadrat Group A, see Figure 5). This species dominated this quadrat, but was not found elsewhere in the survey. The second dichotomy split the remaining quadrats almost equally, with 23 occurring on the positive side and 24 on the negative side. On the negative side, the indicator species were *Brachystegia microphylla, Psydrax livida* and *Dalbergia nitidula*. A further division on this side split a single quadrat from the rest on the negative side to form Groups C1 and C2. Group C2 comprises a single quadrat undertaken on an island and was characterised by the species *Adansonia digitata* which was not found elsewhere in the survey. On the positive side, *Bridelia cathartica, Crossopteryx febrifuga* and *Combretum fragrans* were indicators (Group B).

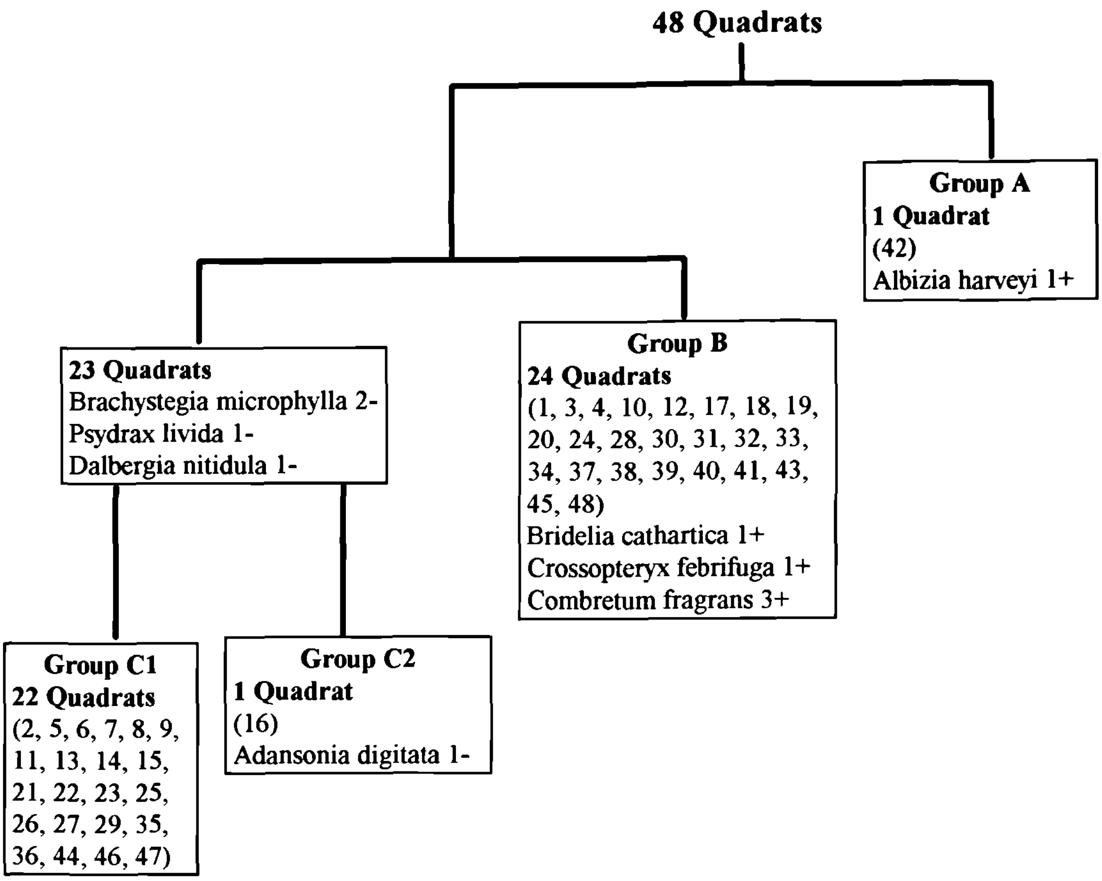


Figure 5. TWINSPAN dendrogram for the site classification indicating the four different quadrat groups and the number of samples at each division.

Quadrat numbers in brackets. Indicator species with preference scores are displayed, the sign indicates on which side of the dichotomy the site was classified. See text for more details and Appendix 4 for complete two-way table produced by TWINSPAN.

Class 1
Albizia harveyi

Class 2
Combretum fragrans
Lonchocarpus capassa
Sclerocarya birrea subsp. caffra

Class 3
Allophyllus africanus
Antidesma venosum
Dalbergiella nyasae
Diplorhynchus condylocarpon
Ficus natalensis
Hugonia orientalis
Lannea discolor
Pseudolachnosytlis maprouneifolia
Pteleopsis myrtifolia
Sterculia africana
Xeroderris stuhlmannii
Erythrina abyssinica
Grewia bicolor
Terminalia stenostachya
Flacourtia indica
Steganotaenia aralicea
Zanha africana
Diospyros kirkii
Ozoroa reticulata
Afzelia quanzensis
Catunaregum spinosa
Combretum collinum
Combretum zeyheri
Stereospermum kunthianum
Vangueria infausta
Azanza garckeana
Elephantorrhiza goetzei
Lonchocarpus bussei
Sterculia quinquiloba
Xerophyta spendens
Bridelia cathartica
Holarrhena pubsecens
Pleurostylia africana
Vangueriopsis lanciflora
Albizia antunesiana
Bauhinia thonningii
Crossopteryx febrifuga
Dalbergia melanoxylon
Ehretia amoena
Friesodielsia obovata
Monotes engleri
Ormocarpum trichocarpum
Polysphaeria dischistocalyx
Strychnos spinosa
Terminalia sericea
Ximenia caffra

Class 4
Brachystegia microphylla
Dalbergia nitidula
Psydrax livida
Strychnos madagascariensis
Bridelia micrantha
Dielsiothamnus divarticus
Vitex doniana
Combretum mossambicensis
Lannea schimperi
Lecaniodiscus fraxinifolius
Dichrostachys cinerea
Ficus capensis

Class 5a
Acacia nilotica
Commiphora merkeri
Euphorbia matabalensis
Ochna rovumensis
Olax dissitiflora
Combretum molle
Croton grattisimus
Euclea natalensis
Garcinia huillensis
Haplocoelum foliolosum
Hugonia busseana
Milletia sericiea
Monanthotaxis buchananii
Ochna holstii

Class 5b
Adansonia digitata
Albizia glaberrima
Boscia angustifolia
Brachystegia bussei
Canthium frangula
Commiphora mariothii
Euphorbia ingens
Ficus abutifolia
Pouzolzia hypoleuca
Turraea robusta
Commiphora caerulea
Diospyros quiloensis
Margaritaria discoidea
Markhamia obtusifolia

Figure 6. TWINSPAN dendrogram for species classification indicating the six different vegetation classes used in this analysis.
See Appendix 4 for the full two-way table.

In the species classification, TWINSPAN separated a species found only in one quadrat, *Albizia harveyi*, at the first division (Class 1 species, see Figure 6). The next division split three species away from the rest (Class 2 species). Their appearance at the bottom of the two-way table (see Appendix 4) suggests that they do not fit into the overall table trend (Kent and Coker 1992). The subsequent dichotomy split the remaining 86 species into two groups of approximately equal size: one containing 46 species (Class 3) and the other 40 species. The latter dichotomy may be subdivided twice more to form three species groups (Classes 4, 5a and 5b). All the divisions are clearly shown in Figures 5 and 6. Interpretation of the TWINSPAN output will therefore use: four different sample groups (labelled Groups A, B, C1 and C2) and six different species associations (labelled Classes 1 - 4, 5a and 5b).

Indirect ordination, Detrended Correspondence Analysis using DECORANA

Detrended correspondence analysis (DCA) indicates that the overall variation in the species-quadrat data matrix is high (the sum of eigenvalues or sum of squares = 5.798). A sum of squares of greater than 4 units (approximately equal to multiples of the standard deviation of species turnover, see below) suggests there are stands with completely different species compositions and species with a completely dissimilar distribution across the sample stands within the dataset.

Figures 7 and 8, respectively, show the quadrat and species ordination diagrams generated using DCA. The eigenvalue for each axis reflects the maximum dispersion of the species or stand scores on the ordination axis and is thus a measure of the importance of the axis. Eigenvalues range between 0 and 1, but a value of greater than 0.5 denotes a good separation of the data along the axis (Jongman et al. 1995). The first axis has an eigenvalue of 0.780 and explains 13.5 per cent of the variance in the data, and the second axis has an eigenvalue of 0.314. The cumulative percentage variance explained by the first two axes is 18.9 per cent. Although low, this figure is not unusual for ecological data which is generally ‘noisy’ and contains many zero values (Kent and Coker 1992).

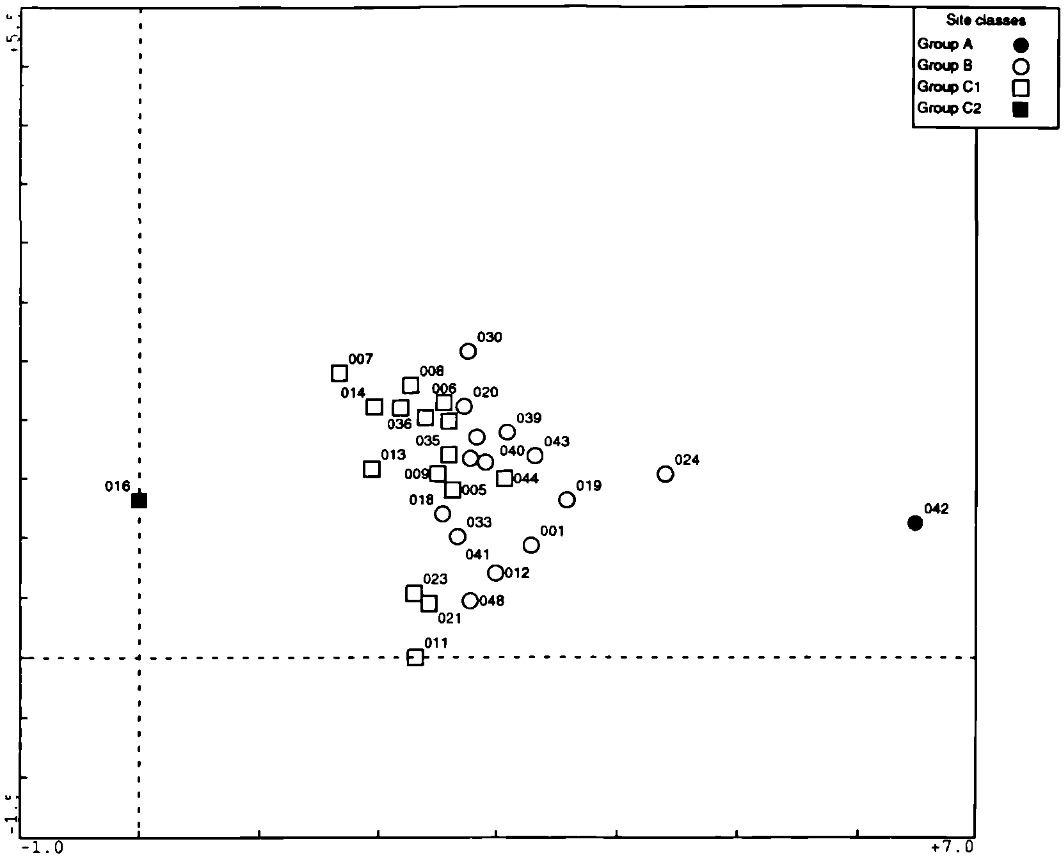


Figure 7. DCA stand ordination plot (axes 1 and 2) with the TWINSPAN classification superimposed.

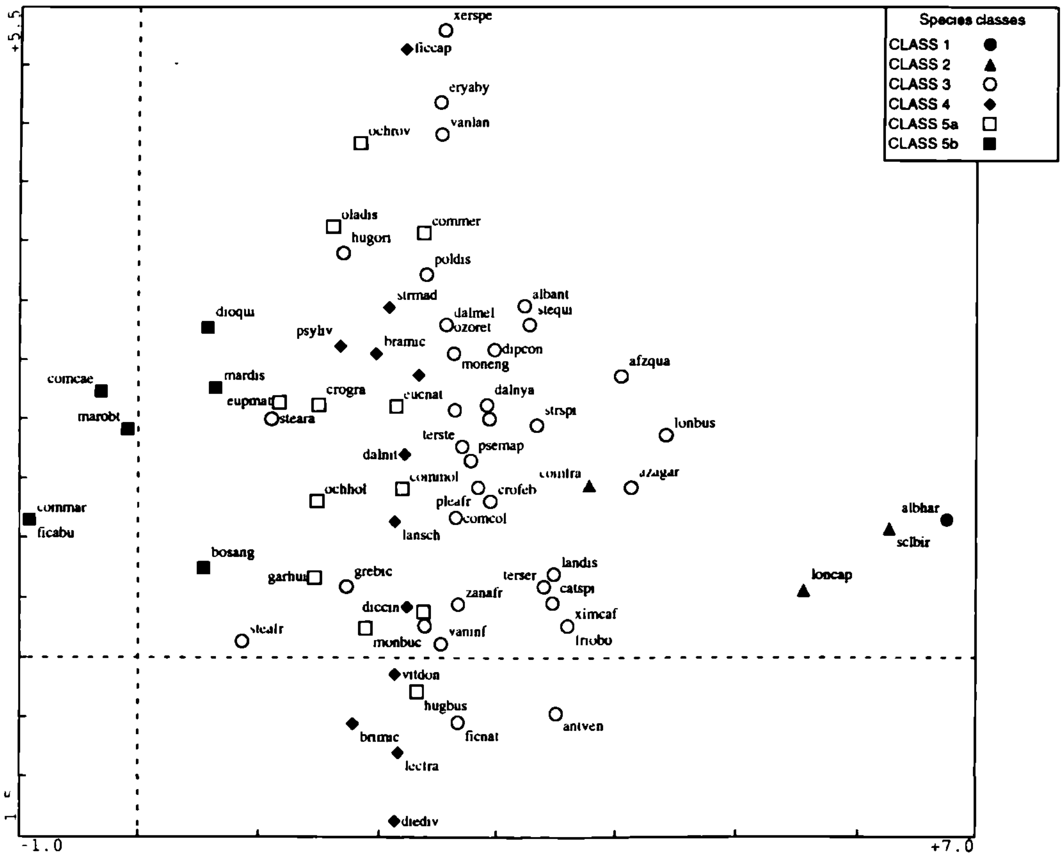


Figure 8. DCA species ordination plot (axes 1 and 2) with the TWINSPAN classification superimposed.

The length of each ordination axis is expressed in units, approximately equivalent to multiples of the standard deviation (SD) of species turnover. Along a gradient, a species appears, rises to its mode and then disappears over a distance of approximately 4 units (or 4 SD) (Kent and Coker 1993, Jongman et al. 1995). Thus, sites that differ by at least 4 units are expected to have no species in common. A change of 50 per cent in the composition of a quadrat (a 'half-change') occurs in about 1 unit. Axis 1 in Figure 7 has a length of approximately 6 units, suggesting that the two outlier quadrats at either end of the axis are highly dissimilar to each other and have no species in common. The remaining quadrats have medium axis 1 scores and appear as a cluster of sites located within a length of less than 4 units. These quadrats are expected to share many common species, with quadrats located close together having a more similar species composition than quadrats located further apart.

Species ordinations mirror stand ordinations. Hence, sites that lie close to the point for a species are likely to have a high abundance of that species and the expected abundance or probability of occurrence of a species decreases with distance from its position in the plot (Jongman et al. 1995). Thus, the species ordination (Figure 8) shows a similar pattern to the stand ordination: species associated with the outlier quadrats are separated from the rest of the species, which have a more general distribution across the remaining quadrats.

The two outlier quadrats were then removed and the DCA was re-run. This is recommended for effective use of the program (Goldsmith et al. 1986, Kent and Coker 1992, Jongman et al. 1995), and allows better ordination of stands and species that appear clustered when outliers are included. Although the overall variation in the reduced dataset was lower (sum of eigenvalues = 4.586), the cumulative percentage variance of the species data explained by the first two axes is 17.6 per cent, similar to results from the first ordination. The ordination diagrams for the second quadrat and species ordination are shown in Figures 9 and 10.

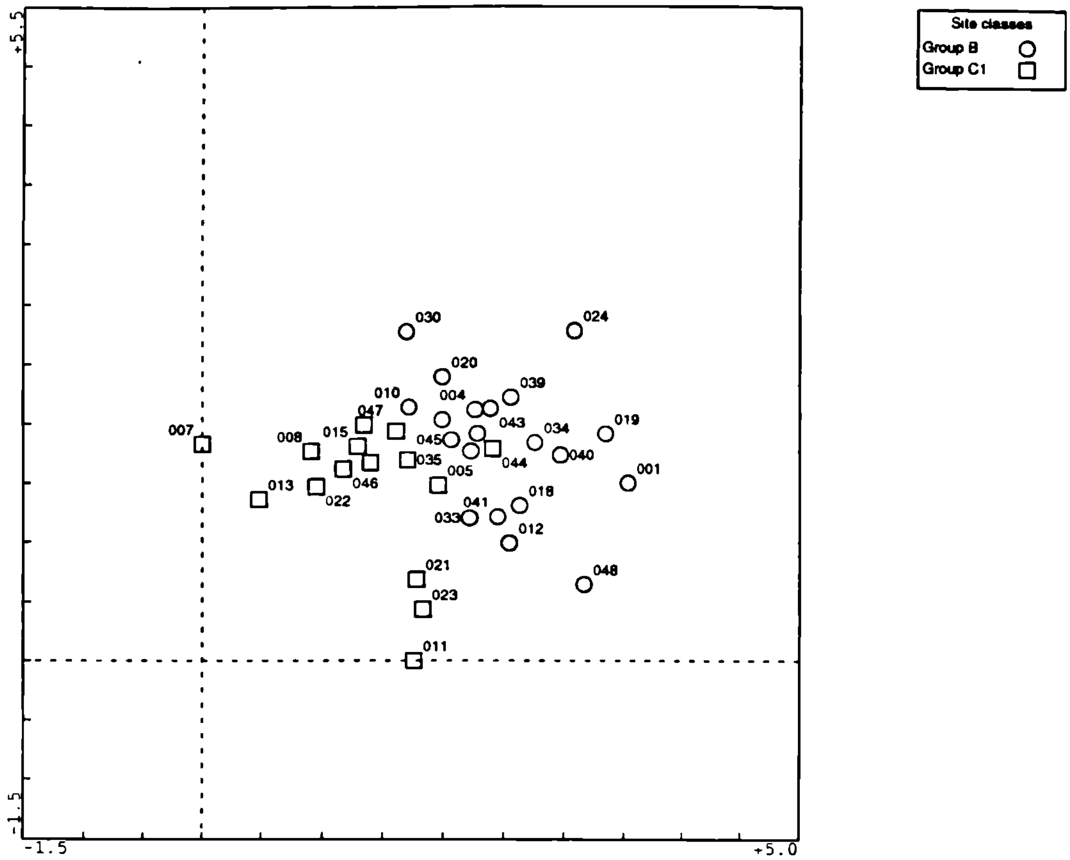


Figure 9. DCA stand ordination plot (axes 1 and 2) with the TWINSPAN classification superimposed. Outlier quadrats removed. See text for details.

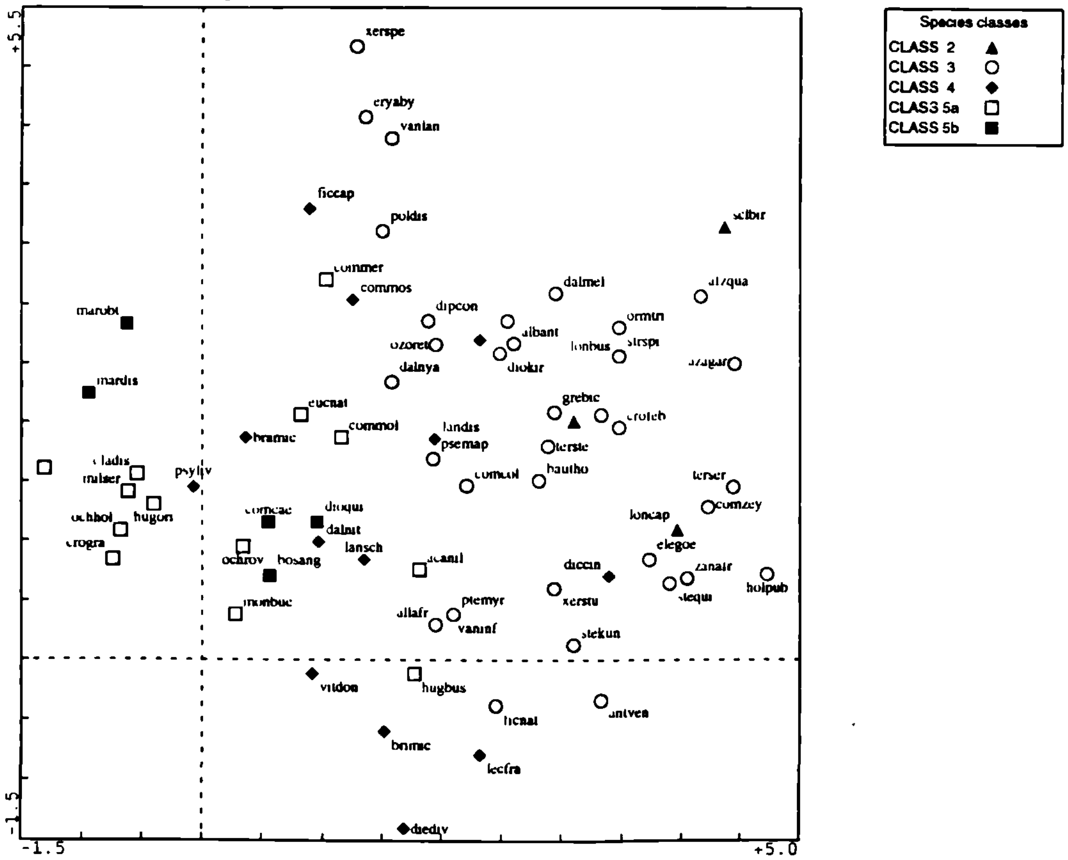


Figure 10. DCA species ordination plot (axes 1 and 2) with the TWINSPAN classification superimposed. Species associated with the outlier quadrats removed. See text for details.

The values of environmental variables were then superimposed on the quadrat ordinations as proportional circles to assist interpretation of their floristic composition (i.e. larger circles reflect larger values of the environmental variables) Figures 11 - 15 show the environmental plots for the following measured environmental variables: position of the quadrat on the slope, altitude, relative accessibility, canopy and slope. For ease of identifying any patterns or trends, environmental scales rather than absolute value were plotted for continuous data (i.e. altitude and slope) (cf. Kent and Coker 1992).

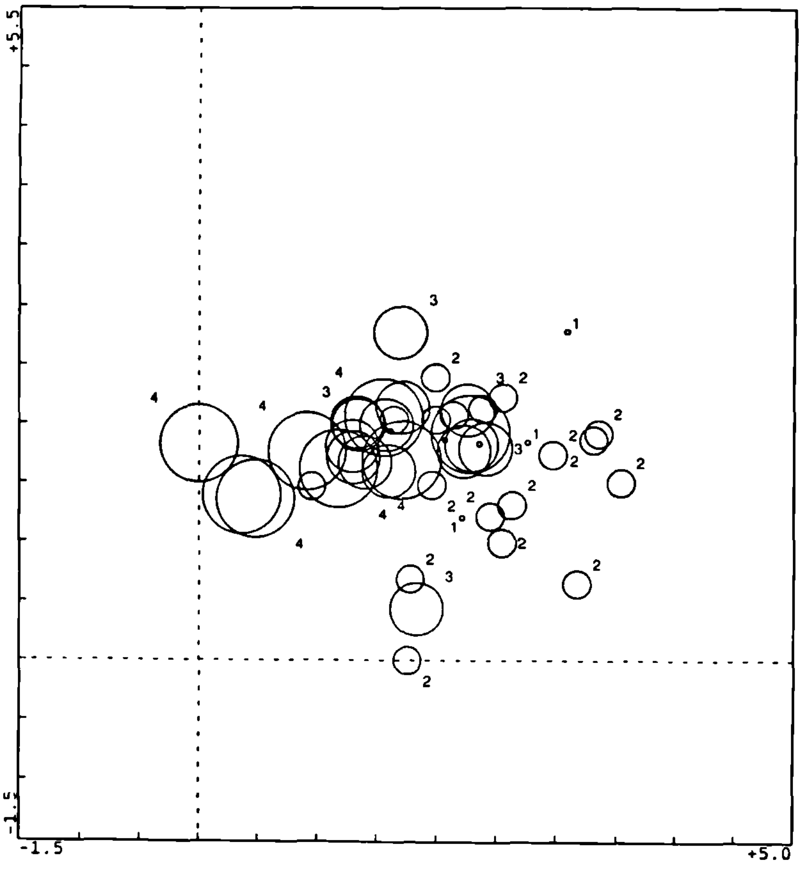


Figure 11. DCA stands ordination plot (axes 1 and 2) with the position of each quadrat on the slope superimposed.
Scale 1 = *dambo* (flood plain), **2** = lower slope, **3** = mid-slope, **4** = upper slope.

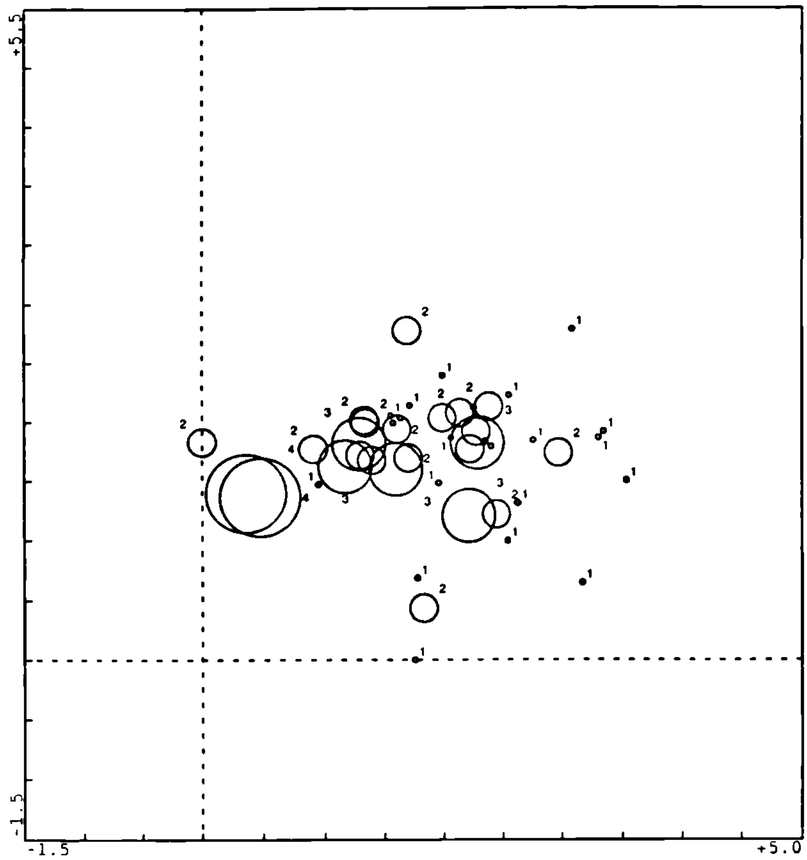


Figure 12. DCA stands ordination plot (axes 1 and 2) with the altitude for each site superimposed.
Scale **1** ≥ 1600 < 2000 m, **2** ≥ 2000 < 2500 m, **3** ≥ 2500 < 3000 m, **4** ≥ 3000 m.

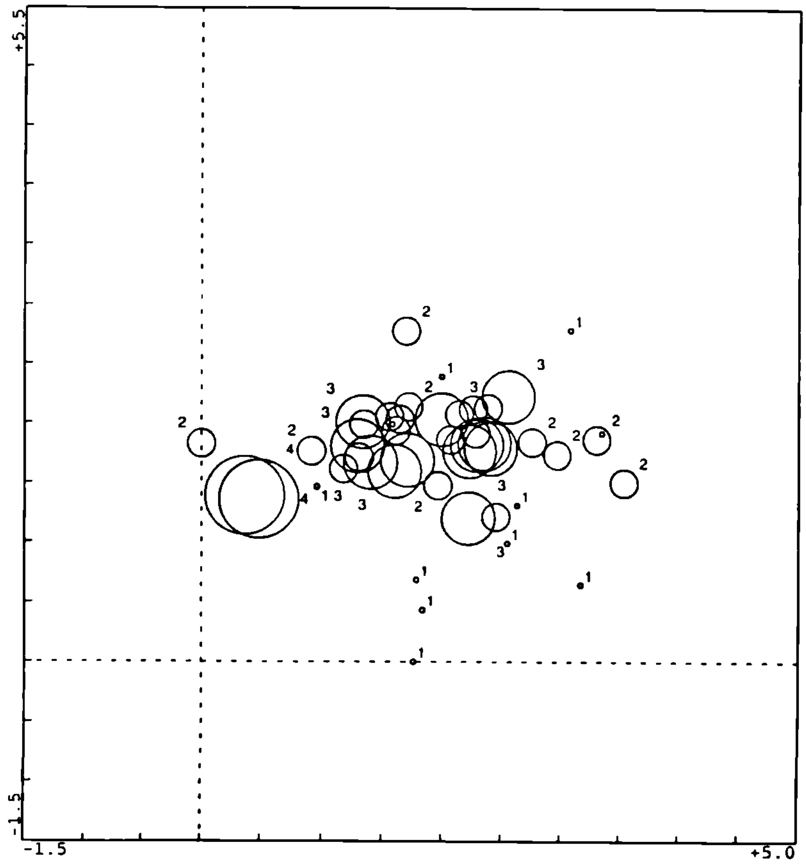


Figure 13. DCA stands ordination plot (axes 1 and 2) with the accessibity of each site superimposed.
Scale **1** < 0.5 hr, **2** ≥ 0.5 < 1.0 hr, **3** ≥ 1.0 < 1.5 hr, **4** ≥ 1.5 < 2.0 hr.

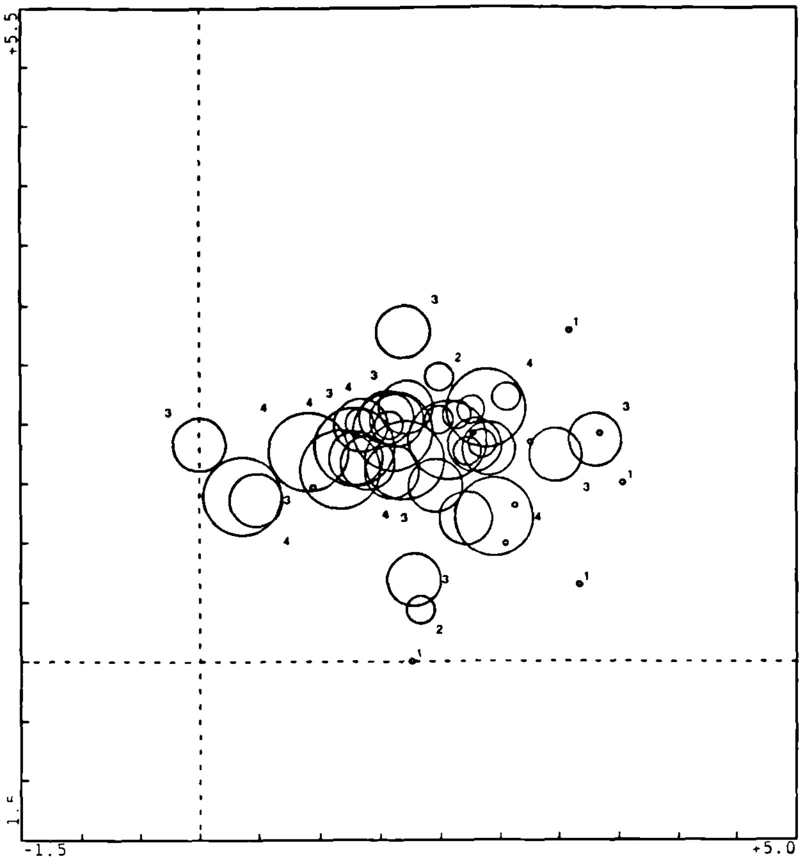


Figure 14. DCA stands ordination plot (axes 1 and 2) with the canopy cover of each site superimposed.

Scale **1** no canopy cover, **2** adjacent crowns don't meet, **3** adjacent crowns meet, **4** crowns overlap allowing light penetration.

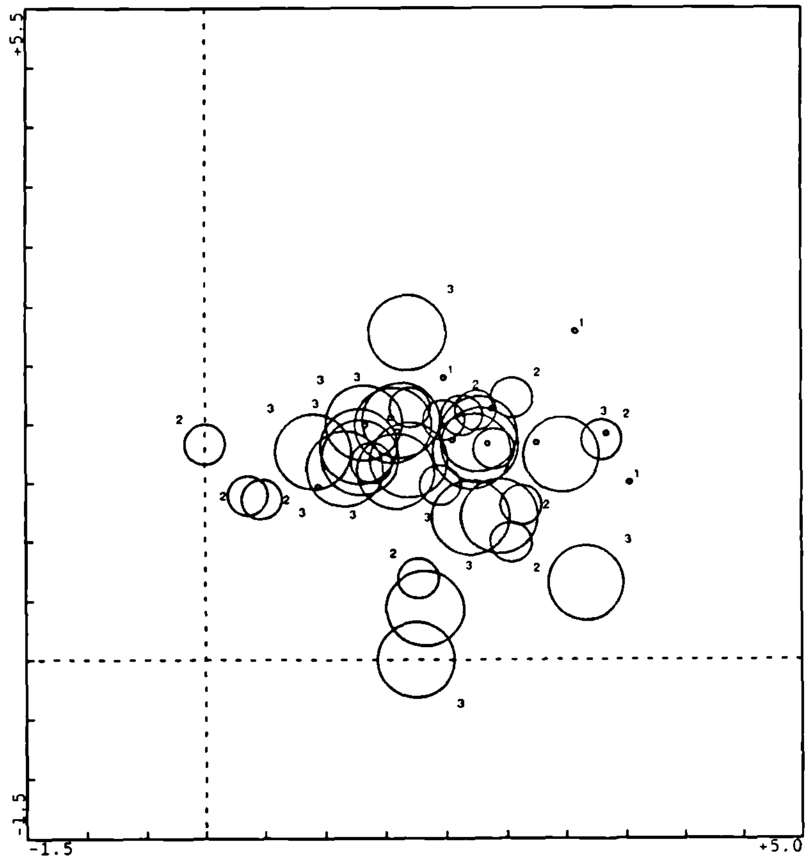


Figure 15. DCA stands ordination plot (axes 1 and 2) with the slope of each quadrat superimposed.

Scale 1 $\geq 0 < 10°$, **2** $\geq 10 < 20°$, **3** $\geq 20 \leq 30°$.

Direct ordination, Canonical Correspondence Analysis using CANOCO

Canonical Correspondence Analysis (CCA) and associated Monte Carlo permutation tests were used to: detect vegetation gradients, relate vegetation composition to measured environmental variables and test whether environmental variables have a statistically significant impact on floristic composition. Figure 16 shows the quadrat-environment biplot obtained from gradient analysis of known environmental basis. For clarity, the species ordination diagram, rather than the species-environment biplot, is presented in Figure 17.

For interpretation purposes, the arrow for an environmental variable points in the direction of maximum environmental change of that environmental variable across the diagram, and may be extended backwards through the central origin. Its length is proportional to the magnitude of change in that direction. Environmental variables with longer arrows (such as altitude or canopy cover) are more strongly correlated with the ordination axes than those with short arrows (such as slope), and are therefore more closely related to the pattern of community variation shown in the ordination diagrams.

A point corresponding to an individual species or stand may be related to each arrow by drawing a perpendicular from the line of the arrow to the point. The order in which the points project on to the arrow is an indication of the position of the species relative to the environmental gradient. Species or samples with their perpendicular projections near the tip of the arrow are strongly correlated with and influenced by the arrow (Wassen et al. 1990, Kent and Coker 1992). The position of each arrow with respect to each axis indicates how closely correlated the axis is with that factor (Kent and Coker 1992). Table 1 suggests that Relative Accessibility is more closely correlated with the first axis than the second, while the other environmental factors (altitude, position of the quadrat on the slope, canopy cover and slope) are more closely correlated with the second axis than the first. Thus, axis 1 reflects relative accessibility while axis 2 reflects a wider range of variables, including position on the slope, canopy cover and altitude.

Table 1. Weighted correlation matrix of species, sample and environmental data from which the CCA ordination diagram is constructed.

Environmental variable	Species Axis 1	Species Axis 2	Environ. Axis 1	Environ. Axis 2
Slope	.3068	.3479	.3465	.398
Altitude	-.2793	.6364	-.3155	.728
Relative accessibility	.5421	.4292	.5920	.491
Canopy	.3683	.6266	.4160	.717
Position	-.0978	.7549	-.1105	.864

The overall variation in the data set is high (sum of eigenvalues = 5.798). The first two axes explain 14.6 per cent of the cumulative percentage variance of the species data (sum of canonical eigenvalues = 1.406). The first axis has an eigenvalue of .515 and explains 8.9 per cent of the variance in the data, demonstrating that it is nearly twice as important as the second axis. Although these values appear low, environmental data is generally noisy and thus the values suggest that the environmental variables selected explain well the variation in species data.

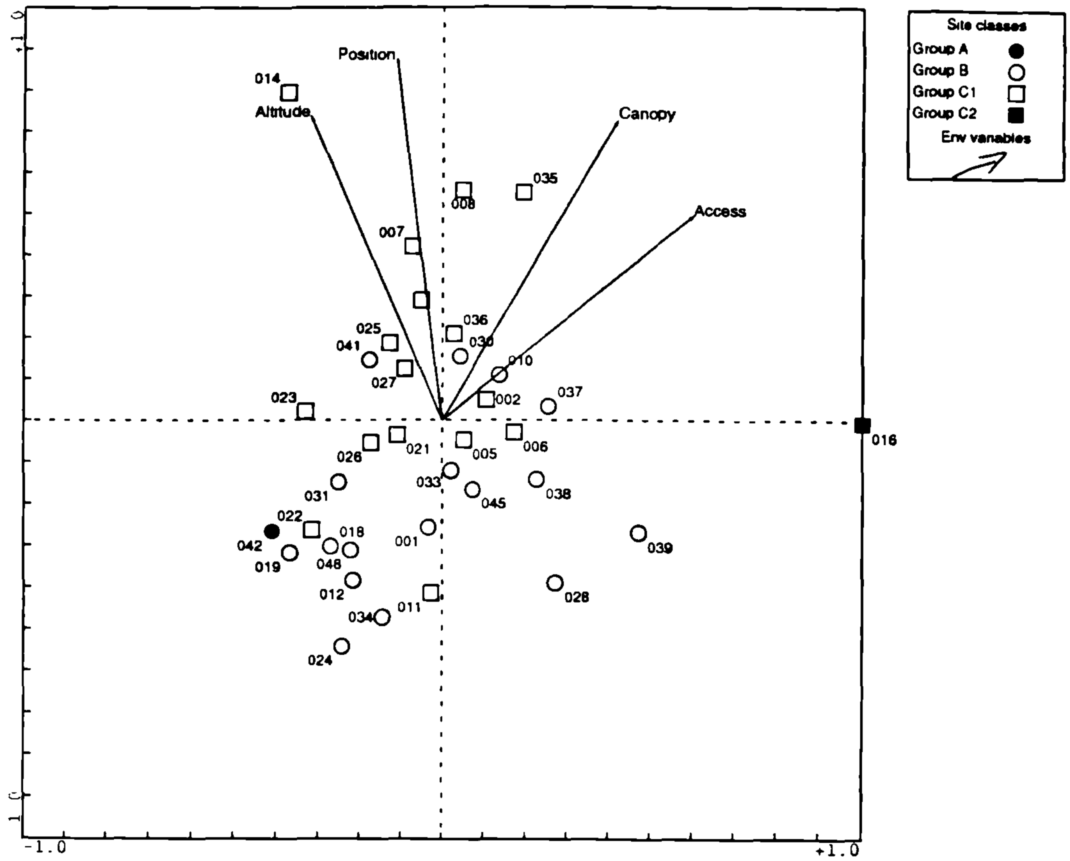


Figure 16. CCA ordination biplot (axes 1 and 2) for stand and environment data with the TWINSPAN classification superimposed.

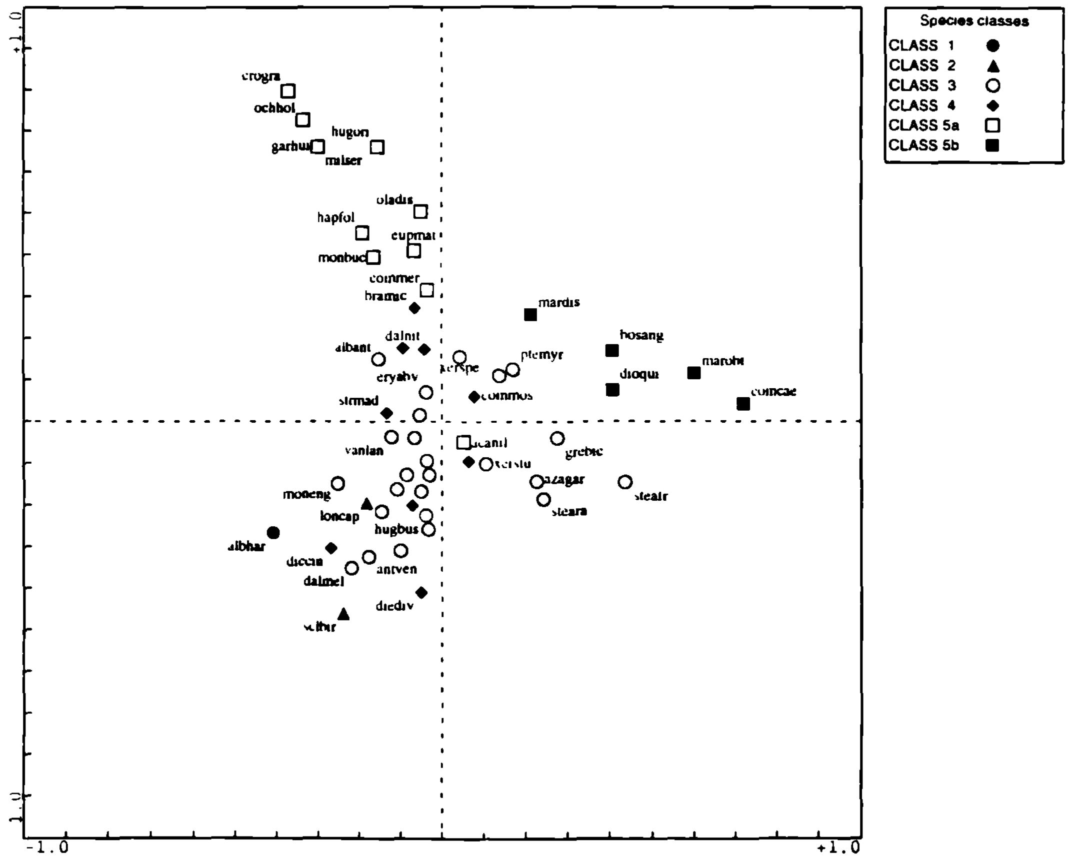


Figure 17. CCA species ordination plot (axes 1 and 2) with the TWINSPAN classification superimposed.

Monte Carlo Permutation Testing

The results of the CCA and associated Monte Carlo Permutation Testing (using 99 permutations) in Table 2 suggest that each of the measured environmental variables has a statistically significant influence on the floristic composition of the *miombo* woodland.

Table 2. Results of unrestricted Monte Carlo permutation tests designed to test the null hypothesis that the measured environmental variables have no impact on the species data.

Environmental Variable	Eigenvalue	Percentage variance explained	Probability (p)
Slope	0.249	4.3	0.01
Altitude	0.285	4.9	0.03
Relative Accessibility	0.320	5.5	0.01
Canopy	0.298	5.1	0.01
Position	0.280	4.8	0.01

However, the weighted correlation matrix from which the ordination diagram is drawn (Table 1) suggests that axis 1 reflects relative accessibility while axis 2 reflects position of the quadrat on the slope. As these appear to be the primary gradients that influence the floristic composition of the samples, partial CCA was undertaken to analyse the co-variance of the two gradients. This technique tests the statistical significance of the two environmental variables independently of one another i.e. the alternate environmental variable is partialled out statistically as a co-variable. Table 3 suggests that these two major environmental co-variables, position of the quadrat on the slope and its relative accessibility, have an independent, statistically significant impact on vegetation composition.

Table 3. Results of unrestricted Monte Carlo permutation tests designed to test the null hypothesis that two measured environmental variables have no impact on the species data when the alternative variable is partialled out statistically as a co-variable.

Environmental variable	Partialled out Co-variable	Percentage variance (after co-variables removed)	Probability (p)
Position	Relative Accessibility	4.9	0.01
Relative Accessibility	Position	5.6	0.03

Discussion

This section begins with a discussion of the results of the TWINSPAN cluster analysis. This classification is used in the subsequent sections to assist interpretation of the ordinations implemented through DECORANA and CANOCO computer programmes. These are used to interpret floristic composition and quadrat groups in terms of measured environmental variables. The Conclusion section integrates the findings of the different analyses and discusses the implications of this research for the future management of LMNP woodlands.

Vegetation classification

Using the TWINSPAN dendrograms (Figures 5 and 6) and two-way table (Appendix 4), an assessment of the vegetation communities is best made through a simultaneous analysis of species and stand classifications. Although a complete site history for LMNP is not available, the quadrat groups may be interpreted in terms of their floristic composition. Thus, the past history of land-use within LMNP may be reconstructed using a literature review of *miombo* ecology and the impact of management practices on floristic composition. The importance of various physical and anthropogenic factors that influence the floristic composition of *miombo*, and related woodland types, has been outlined earlier in this chapter. From studies in Zambia and Tanzania, Lawton (1978) and Kikula (1986) suggest there is a dynamic relation between three vegetation types with a trend, in the absence of fire, from *chipya* (an open woodland subjected to intense dry season fires) to *miombo* (a light closed canopy woodland) and, ultimately, to *mateshi* or *muhulu* (dry, evergreen forest).

Using the TWINSPAN classification outlined previously (see Figures 5 and 6), quadrat groups and species classes may be interpreted in terms of this dynamic succession. The fire tolerance of 41 of the species surveyed (48 per cent of those encountered) is inferred from published research by Trapnell (1959), Lawton (1978) and Kikula (1986). The results are shown in Table 4. This table also documents to which side, either positive or negative, each species was allocated by TWINSPAN at the third dichotomy. This is the dichotomy that split the species into two approximately equal groups, with 46 species on the positive side (assigned Class 3) and 40 species on the negative side (assigned Classes 4, 5a and 5b, see Figure 6 and Results section for a full description).

Twenty five of the species found at LMNP have their fire tolerance recorded in the literature. Additional fire tolerances were provided by researchers with extensive experience with *miombo* woodland (Lowore and Abbot: Forestry Research Institute of Malawi, Lawton pers. comm.). Where species are marked with an asterisk, their fire tolerance is inferred as being similar to that of another species in the same genus, whose fire tolerance is documented. However, tolerance within a genus may vary, as for example with *Ochna* spp., and conflicting evidence regarding tolerance may be documented (e.g. *Garcinia huillensis*). Such species were excluded from analyses.

For species recorded in Table 4, those less tolerant of fire are generally found on the negative side of the dichotomy and species with greater fire tolerance are found on the positive side. Using Trapnell's (1959) assessment of fire tolerance, the negative side of the dichotomy consists primarily of species that are either sensitive to fire ('fire-tender' species) or, at best, semi-tolerant of fire. Species on the positive side are generally either semi-tolerant of, or relatively resistant to ('fire-tolerant' species), the effects of fire. Using Lawton (1978) and Kikula's (1986) classification of species into ecological groups, species on the positive side of the dichotomy belong predominantly to the *chipya* ecological group, which can withstand intense dry season fires. Fire sensitive species belong primarily to either the *miombo* or evergreen ecological groups. These species tend to occur on the negative, rather than positive, side of the dichotomy.

Table 4. Species tolerance to fire and their classification by TWINSPAN.

Species	Ecological Group [1]	Fire tolerance [2]	Dichotomy
Combretum molle	*Chipya*		-
Ochna rovumensis *	*Chipya*/ Evergreen	ST/S	-
Croton gratissimus *	Evergreen		-
Euclea natalensis	Evergreen		-
Garcinia huillensis	*Chipya*	S	-
Ochna holstii *	*Chipya*/ Evergreen	ST/S	-
Albizia glaberrima *	Ubiquitous		-
Boscia angustifolia	Evergreen		-
Brachystegia bussei	*Miombo*	S	-
Canthium frangula *	Evergreen/ Ubiquitous		-
Diospyros quiloensis *	*Chipya*		-
Brachystegia microphylla	*Miombo*	S	-
Dalbergia nitidula	*Chipya*		-
Strychnos madagascariensis *	*Chipya*/ Evergreen	ST	-
Bridelia micrantha	Evergreen		-
Vitex doniana	*Chipya*		-
Combretum mossambicensis *	*Chipya*		-
Lannea schimperi *	Ubiquitous		-
Diplorhynchus condylocarpon	*Chipya*	T	+
Lannea discolor	Ubiquitous	ST	+
Pseudolachnostylis maprouneifolia	*Chipya*	ST	+
Terminalia stenostachya *	*Chipya*		+
Flacourtia indica	*Miombo*		+
Steganotaenia aralicea	Ubiquitous		+
Zanha africana	*Chipya*		+
Diospyros kirkii	*Chipya*	ST [4]	+

Species	Ecological Group [1]	Fire tolerance [2]	Dichotomy
Ozoroa reticulata	*Chipya*		+
Afzelia quanzensis	Evergreen/ *Chipya* [3]		+
Catunaregum spinosa	Ubiquitous	ST/T [4]	+
Combretum collinum	*Chipya*		+
Combretum zeyheri	*Chipya*		+
Stereospermum kunthianum	*Chipya*		+
Vangueria infausta *	*Chipya*		+
Lonchocarpus bussei *	*Chipya*		+
Bridelia cathartica	*Miombo*	ST	+
Albizia antunesiana	Ubiquitous		+
Dalbergia melanoxylon *	*Chipya*		+
Monotes engleri *	*Miombo*		+
Strychnos spinosa	*Chipya*	T	+
Terminalia sericea	*Chipya*	ST [4]	+
Ximenia caffra	*Chipya*		+

[1] Lawton (1978) and Kikula (1986) both record the ecological group to which species belong, as defined below:

Chipya (C), includes fire-hardy species intolerant of shade. They grow in habitats where fire intensity is high.

Miombo (M), includes Brachystegia species. They need some protection from fire if they are to grow through the sapling stage to form mature trees. They do not grow under *chipya* conditions.

Evergreen (E), fire sensitive and evergreen trees unable to withstand dry season fires (includes *mateshi* and *muhulu*)

Ubiquitous (U), species tolerant of fire and shade, wide ecological range.

[2] Trapnell (1959) records the tolerance of each species to fire:
fire-tolerant (T), semi-tolerant (ST) and fire-tender or fire-sensitive (S).

[3] *Afzelia quanzensis* may also occur in *chipya* (Lawton pers. comm.)

[4] Additional fire tolerances were provided by the Abbot and Lowore (pers. comm.) at the Forestry Research Institute of Malawi (see FRIM 1995).

Nine fire sensitive species occur in Table 4. Their fire tolerance is categorised as either *miombo* or evergreen by Lawton (1978) and Kikula (1986). Six of these species occur on the negative side of the dichotomy and three on the positive side. An analysis of the enumeration data shows that a total of 363 individual trees, comprising the nine fire sensitive species, were encountered during the vegetation survey. Of these, 301 trees comprising six fire sensitive species were found on the negative (or fire sensitive side) of the dichotomy, while just 62 trees (from three fire sensitive species) were found on the positive side of the dichotomy (comprising, predominantly fire tolerant, *chipya* species).

Thus, the classification may be interpreted in terms of species fire tolerance. It suggests that quadrats including more species from the negative side of the dichotomy (Classes 4, 5a and 5b) have had less exposure to fire than quadrats on the positive side (Class 3). Hence, species on the negative side of the classification tend to be fire sensitive, *miombo* or evergreen species, while those on the positive side show greater fire tolerance and comprise species predominantly from the *chipya* ecological group. Werger and Coetzee (1978) describe *chipya* as degraded *miombo* because *Brachystegia* spp. are absent, although other fire tolerant *miombo* species may be found in greater abundance in *chipya* than in *miombo*.

Because of the patchy nature of burning within LMNP, it is not surprising that some fire sensitive species (e.g. *Bridelia cathartica*) occur, at low density, on the positive side of the dichotomy which contains species that are generally fire tolerant. Kikula (1986) notes that the presence of such species indicates highly localised, spatial variation in fire intensity. Moreover, Huston (1994) notes that low intensity fires produce a high degree of small-scale heterogeneity in their effects on vegetation since 'slight variability in fuel amount and moisture is sufficient to determine whether a particular area will or will not burn.' By contrast high intensity fires tend to produce large areas that are uniformly burned.

Chipya species may survive in the absence of fire and these species occur on both sides of the dichotomy. However, there are fewer *chipya* species on the negative (or fire sensitive) side of the dichotomy. *Chipya* species are shade intolerant and are unlikely to thrive under a *miombo* canopy (Lawton 1978). Clearly, ubiquitous species are found on both sides of the dichotomy.

Turning to the sample classification, two quadrats were isolated by TWINSPAN (allocated to Groups A and C2). The Group C2 single sample was enumerated on Thumbi Island

West (see Chapter 1, Figure 1). The island's relative inaccessibility safeguards it from human disturbance and fires. It has a distinct species composition that may be explained both by this protection and its proximity to water (see below). Table 5 shows the sample contains a high density of understorey trees. This is consistent with Malaisse's (1978) observations that woodlands spared from fire develop into a dense structure (known as *foret claire muhuluteuse*), characterised by a dense understorey, the presence of lianas and accumulation of litter.

Table 5. Tree density and woodland stratification.

Parameter	Group A	Group B	Group C1	Group C2
No. quadrats	1	24	22	1
Average number of trees per quadrat	23	46	43.5	147
% of trees that are canopy trees per quadrat	30.4%	6.35%	14.0%	4.8%
Total number of canopy trees	7	57	77	4
% of canopy trees that are fire-sensitive [1]	0%	24.6%	60.2%	25.0%
Brachystegia spp. as % of canopy trees	0%	24.6%	59.3%	25.0%
D. condylocarpon as % of canopy trees	0%	24.6%	14.8%	0%

[1] fire sensitive species encountered in the canopy include *Brachystegia bussei, B. microphylla* and *Bridelia micrantha.*

The island sample contains some species from Classes 3 and 4, but is defined by Class 5b species (see Appendix 4). These species show a highly localised distribution throughout the rest of LMNP. As outlined previously, this Class tends to include the fire sensitive species, including succulents and evergreens. Interestingly, a second species of *Brachystegia, B. bussei,* was surveyed on the island which was not found on the peninsula. Class 5b species are characterised by species such as *Adansonia digitata, Euphorbia ingens* and *Albizia glaberrima,* which grow in low altitude, hot dry woodlands (Coates Palgrave 1983). Other species, such as *Canthium frangula, Diospyros quiloensis* and *Pouzolzia* *hypoleuca* tend to grow along watercourses (Shorter 1989), forming riverine, or as in this case, lacustrine thicket (Coates Palgrave 1983).

The other single quadrat (allocated to Group A) contrasts sharply with the island sample. Table 5 shows that Group A has a low tree density. It is dominated by standards of *Albizia harveyi* and *Sclerocarya birrea* subsp. *caffra*, with an understorey of *Combretum fragrans* (i.e. Class 1 and 2 species). The proportion of canopy trees appears high but the canopy was incomplete because of the low tree density. The scant understorey was ill-defined. This sample had been heavily burnt and the complete absence of *miombo* species is attributed to the high level of disturbance. These observations (taken from the system notes recorded during the survey) are consistent with Werger and Coetzee's (1978) observations that plots with a history of late burning become virtually devoid of trees.

Group C1 quadrats contain fire sensitive species from Classes 4 and 5a, together with some species from Class 3, which show greater fire tolerance. These quadrats are typical *miombo,* containing the canopy dominant species *Brachystegia microphylla* (Trapnell 1959, Lawton 1978, Kikula 1986). Woodland stratification in Table 6 shows that Group C1 quadrats have a high proportion of canopy trees. These comprise both *Brachystegia microphylla* and the co-dominant *D. condylocarpon,* although more than half of these trees (59.3%) are *Brachystegia microphylla.*

Group B quadrats contain high numbers of fire tolerant species (Class 3) and many fewer fire sensitive species (Classes 4, 5a and 5b) than Group C1 quadrats. The predominance of *chipya* rather than *miombo* species suggests that these quadrats have been exposed to frequent late fires, preventing the maturation of *miombo* species. This is corroborated by the lower proportion of canopy trees in Group B quadrats compared with Group C1 quadrats (Table 5). The canopy layer in these quadrats consists of two co-dominant species, *B. microphylla* and *D. condylocarpon.* Compared with Group C1 quadrats, these quadrats have a lower proportion of *B. microphylla* and a higher proportion of *D. condylocarpon.* This suggests that these quadrats comprise *chipya* woodland, although they may represent a transitional stage between *miombo* and *chipya* vegetation types. In his vegetation survey of LMNP, Bootsma (1987) found frequent fire was a feature of sites dominated by the fire-tolerant *D. condylocarpon.*

While the site history for each quadrat is incomplete, the system notes made during enumeration record evidence of either recent fire or cultivation in the past for ten of the quadrats. All of these quadrats occur in Groups A and B, with none occurring in either Group C1 or C2, the quadrats in which the fire sensitive *miombo* and evergreen species predominate. This again supports the notion that anthropogenic factors have shaped the vegetation of LMNP. Evidence for fuelwood cutting (cut branches or woodcutters paths) was found in quadrats across all Groups A, B and C1, with some cutting even on the island, Group C2. Domestic fuelwood cutting has less of an impact on vegetation than either fire or cultivation because it rarely involves tree-felling (see Chapter 6). Hence while domestic fuelwood collection may alter tree form and possibly canopy dominance, it has less effect on floristic composition or regeneration. Thus, fire and cultivation are the main factors likely to have influenced the vegetation of LMNP.

Indirect species ordination using DCA

Figure 7 shows the quadrat ordination for all vegetation samples with the TWINSPAN groups superimposed. Quadrat 16, enumerated on Thumbi Island West, has a low axis 1 score and is isolated on the left side of the plot. As discussed previously, this woodland community is protected from fire and anthropogenic disturbances. By contrast, Quadrat 42 has a high axis 1 score. This highly disturbed sample (burnt and cut) contrasts sharply with the protected, relatively inaccessible woodland found on the Park's islands. Thus, these two quadrats may be interpreted as forming opposite ends of the spectrum of vegetation types. Quadrat 16 contains some evergreen and succulent communities and a dense understorey, characteristic of protected *miombo* (interpreted as TWINSPAN Class C2). Quadrat 42 appears to be degraded savanna woodland. It has a low density of trees and is characterised by a patchy canopy offered by the fire-resistant *Albizia harveyi* (TWINSPAN Class 1).

Between these two extremes, the remaining quadrats fit into the *chipya-miombo* continuum (Figure 7). Various sample groups may be discerned using floristic composition (Figure 8) and the system notes recorded for each quadrat during enumeration. The quadrats with high axis 1 scores are all disturbed, regrowth plots having been burnt or cultivated in the past. Those with medium axis 1 scores contain a range of open to scrub woodland types. Quadrats with low axis 1 scores contain mature, closed canopy *miombo* woodland. The small group of quadrats with low axis 2 scores are quadrats enumerated on very steep or rocky slopes, offering unfavourable conditions for woodland development. In common with the TWINSPAN classification, an important feature of the ordination is the absence of discrete communities. These data, therefore, support earlier work suggesting a continuum of vegetation types within *miombo* (Boaler and Sciwale 1966, Lawton 1978).

Ordination diagrams of species mirror the sample data. This facilitates the concurrent interpretation of species and stand ordinations (e.g. Figures 7 and 8). The species plot (Figure 8) shows that fire-tolerant species (classified as TWINSPAN Class 2) have high axis 1 scores and occur in the anthropogenically disturbed Quadrat 42. By contrast, fire-sensitive species, classified as TWINSPAN Class 5b, have low axis 1 scores and occur in Quadrat 16, the protected island site. The majority of species are spread centrally along the second axis and are thus found in a range of sites.

Figure 9 shows the second DCA quadrat ordination with the two outliers removed and the TWINSPAN classification superimposed. It shows a greater spread of the quadrats along the first axis. Allocating the samples to the TWINSPAN Quadrat Groups separates the plot into two sections: samples with high axis 1 scores correspond to Group B quadrats (which contain mainly species from the *chipya* ecological group), and those with low axis 1 scores correspond to Group C1 quadrats (characterised by *miombo* species).

Other trends may be seen by using system notes, recorded during enumeration, with floristic composition (Figure 10) to reconstruct patterns of land-use. Quadrats with high axis 1 scores are disturbed samples, all had evidence of either burning, cultivation or, as in the case of Quadrat 48, were situated adjacent to a village. The three quadrats with low axis 2 scores, were described as containing scrub woodland, with stunted trees growing on rocky slopes. The quadrats with low axis 1 scores were described as mature, closed canopy *miombo* woodland. This is corroborated by Figure 10 which shows that the species classified as TWINSPAN Class 5a also have low axis 1 scores. As outlined previously, Class 5a species are fire-sensitive and are found almost exclusively in *miombo*-type vegetation rather than in association with *chipya* woodland. Thus the species and sample ordinations appear to support the interpretation of the TWINSPAN classification that species associations represent a response to disturbance levels.

This is corroborated by the environmental ordination plots of the position of each quadrat on the slope (Figure 11) and altitude (Figure 12). Disturbed quadrats, comprising *chipya* woodland, have high axis 1 scores and occur at low altitude, at the base of slopes (i.e. on seasonally wet land or on lower slopes). *Miombo* woodland quadrats, with low axis 1 scores, occur in less accessible, higher altitude areas (i.e. on the upper slopes of the hills). The quadrats of intermediate *chipya-miombo* composition occur at a range of lower altitude sites.

Altitude is unlikely to account for the differences in vegetation at different sites. *Brachystegia* woodland occurs from 500 metres in lakeshore localities (Jackson 1968) to 1800m on the central African plateau, although it can occur as high as 2500 metres (Werger and Coetzee 1978). Despite the large altitudinal range for the small size of the Park (lake level at 474 metres to Nkhunguni Peak at 1150 metres), LMNP woodlands lie well within the range at which *miombo* vegetation generally occurs. Thus, rather than altitude *per se*, the results seem to support the importance of disturbance in determining floristic composition. Accessible quadrats at the base of slopes are more likely to have been farmed in the past, before cultivation within the Park woodlands was prohibited in 1980. Similarly, quadrats at the base of slopes are more susceptible, because of their proximity to villages, to anthropogenic fires. Thus, it is perhaps unsurprising that these quadrats are characterised by *chipya*-type vegetation rather than *miombo* woodland. The environmental plots demonstrate a trend towards *miombo* woodland at less accessible quadrats, which occur at higher altitude on upper hill slopes.

Environmental plots of other ecological variables (relative accessibility, canopy and slope) are shown in Figures 13 - 15 and support the hypothesis for disturbance influencing floristic composition. Figure 13, the environmental plot for the relative accessibility of each quadrat, demonstrates that *chipya*-type vegetation (with high axis 1 scores) occurs at sites that are the most accessible to local communities. By contrast, *miombo* woodland occurs at less accessible sites (lower axis 1 scores), which are likely to receive less disturbance from the local communities. The canopy cover afforded by each plot is shown in Figure 14. It suggests that highly disturbed quadrats also have a less developed canopy structure than the *miombo* quadrats. This is expected as *chipya* vegetation supports an open, patchy canopy of normally understorey trees, of which a few species (e.g. *D. condylocarpon*) achieve canopy status in the absence of fire-sensitive *Brachystegia* and other typical canopy dominants (Lawton 1978). By contrast, closed canopy plots (low axis 1 scores) comprise a range of *miombo* type communities, including mature *miombo* with the most fully developed canopy structure.

Figure 15 plots the slope of each quadrat and shows a less clear pattern with the gradient of the slope appearing to have little impact on the vegetation composition. This may be explained because angle of slope, unlike the other factors, is not linked to a quadrat's position within the Park i.e. steep and gradual slopes may occur anywhere on a hillside, both near and far from villages and at high and low altitude.

Direct ordination using CCA and associated Monte Carlo Permutation Testing

Figure 16 shows the environment-sample biplot obtained using CCA. Interpretation of this plot, in conjunction with the species plot (Figure 17), corroborates the findings of the vegetation classification and indirect ordination. Quadrats that are strongly positively correlated with high altitude and are positioned higher on slopes are those characterised by *miombo*-type, fire-sensitive species (species from Class 4 and 5a). Conversely, fire tolerant species (Class 2 and 3) that characterise *chipya*-type vegetation tend to be found at lower altitude and at positions lower on the slope. The highly disturbed sample (quadrat 42), containing the fire tolerant *Albizia harveyi* (Class 1 species) is positioned with the *chipya* samples in its response to the measured environmental variables.

Thus, the *chipya* samples (TWINSPAN Groups A and B) are associated with low levels of canopy cover and tend to be more accessible to local communities. *Miombo* quadrats (TWINSPAN Group C1) tend to be highly positively correlated with full canopy cover, a characteristic of *miombo* woodland (Lawton 1978). They are also less accessible i.e. projections from stand centres approach the tip of the arrow for remote or more difficult to access sites. Figure 16 also suggests that Quadrat 16 (TWINSPAN Group C2) is an outlier, highly dissimilar to the other quadrats. Undertaken on an island, the sample has an unusual floristic composition, including species with a highly localised distribution throughout the rest of the Park (TWINSPAN Class 5b species, see Figure 17, also Appendix 4).

Monte Carlo Permutation tests confirm that each of the measured environmental variables had a significant effect on floristic composition (Table 2). Furthermore, Table 3 suggests that two major environmental co-variables, position of the quadrat on the slope and its relative accessibility, have an independent, significant impact on vegetation composition. Thus, there appear to be two independently important gradients which affect the floristic composition of the LMNP woodlands. An important consequence of these gradients appears to be the level of disturbance that impacts upon a site as this is a key determinant of floristic composition.

Conclusions

The multivariate analyses have helped elucidate the nature of community variation through displaying the distribution of individual species and the relationship between species assemblages and various environmental factors. The robustness of pattern in the data is affirmed by the similar species and stand associations produced by each of the techniques.

Lawton (1978) concludes that the floristic composition and dynamic ecology of *miombo* are the product of factors both natural and anthropogenic in origin including: agricultural systems, fire and topography. The present study also suggests that the specific vegetation associations at any site appear to reflect a complex interaction of factors. Certainly, physical factors, such as altitude and position of the sample on the slope, influence species composition. Indeed Boaler (1966) and Kikula (1979, in Kikula 1986) found that species composition in *miombo* vegetation varied with topography and the position of each sample on the slope. However, the catena of vegetation noted by Boaler did not represent separate floristic entities: 'the vegetation represented by a group merges (on the ground) imperceptibly into that of the groups on either side'.

A vegetation continuum is also observed in this study, although the presence and specific distribution of both *chipya*- and *miombo*-type species associations suggests a response to influences other than physical position. It is postulated that anthropogenic disturbance is a key determinant of floristic composition - the influence of human activities on floristic variation within *miombo* vegetation being well documented in the literature (e.g. Trapnell 1959, Lawton 1978). Moreover, physical and anthropogenic factors work concurrently: accessible sites (at low altitude and on lower slopes) are subjected to greater levels of human disturbance from villages situated on the flood plain. Thus, the vegetation appears to be a consequence of a complex gradient of physical factors (e.g. altitude and position on slope) on which other factors (e.g. anthropogenic effects, particularly fire) are operating.

Specifically, these analyses reveal the importance of two environmental gradients, accessibility and position on the slope, which together represent some index of the potential for disturbance. The present analyses suggest the local population is an important determinant of the floristic composition of the Park woodlands. Sites proximate to the enclave villages are subject to high levels of disturbance and comprise fire-tolerant *chipya* woodland. Fire sensitive, succulent and evergreen *miombo* species are confined to less accessible sites within the Park, such as on islands or at high altitude on upper hill slopes.

Trapnell (1959) has shown that annual late burning will destroy the coppice of *miombo* dominants and that their regeneration requires an early burning regime to be adopted. Lawton (1978) suggests that some form of protection from fire is required for *miombo* dominants to progress from the coppice stage and form a mature woodland canopy. He also suggests that the vegetation 'depends more on its history of burning than any other single factor, e.g. any direct effect of climatic or edaphic variables'. In his study of LMNP, Bootsma (1987) noted that repeated fires inhibited tree recruitment. This is particularly important for woodland sites proximate to villages where there is a high risk and frequency of fires. Thus, to ensure the maintenance of fire-sensitive *miombo* species (such as *Brachystegia*, whose recruitment is impeded by repeated fires), an early burning strategy should be adopted within the Park.

By contrast, the fire-tolerant *chipya* species that pioneer *miombo* regeneration are capable of withstanding the harsh conditions (e.g. high light intensity and fierce, frequent dry season fires) associated with disturbed areas. Bootsma (1987) recorded that fire tolerant species, such as *D. condylocarpon and P. maprouneifolia*, dominated woodland sites close to villages. The occurrence of *chipya* communities in at least half of the quadrats indicates widespread disturbance throughout LMNP, reflecting abandoned cultivation plots and areas of the Park subjected to an uncontrolled burning regime. Furthermore, the frequent, late fires that maintain *chipya* appear to aggravate erosion by reducing both the protective cover and the humus content and biological activity in the top soil (Christiansson 1981).

These data do not reveal the status of regeneration within *miombo* although fire governs the potential for *miombo* to regenerate (see Trapnell 1959). In the absence of a controlled fire regime and with frequent late fires, fire-sensitive species are unlikely to regenerate and *miombo* communities may be gradually replaced by *chipya* through time. Indeed, Quadrat 42 with its low species diversity and tree density may be indicative of a woodland subjected to consistent late burning (Werger and Coetzee 1978). It demonstrates the importance of controlling fires, through rotating early burning throughout the Park, to maintain canopy cover within the woodlands. While Trapnell (1959) suggested that woodland may be destroyed by late burning, Nyerges (1989) notes that '[t]he coppicing capacity adapts....trees to the periodic loss of above-ground biomass due to drought, fire, or other factors, and confers on the habitat a degree of resilience to disturbance' (see also Stromgaard 1986b). The ability of *miombo* dominants to regenerate through suffrutices is demonstrated by a re-evaluation in 1969 and 1992 of the Ndola plots, first described by Trapnell (1959). Late burning destroys the *miombo* canopy but the extensive root system of *Brachystegia* enables some trees to extend a coppice shoot after 59 years of late burning (Lawton pers. comm.). This suggests that woodland is unlikely to be 'destroyed' by frequent, late-season burns. The apparent resilience of *miombo* species indicates that fire may be used as a management tool to restore *miombo* in areas occupied by *chipya* species.

To maximise species diversity, the management objective in LMNP should be to maintain a dynamic continuum of *chipya* and *miombo* species. *Chipya* species are likely to be maintained in areas proximate to villages with a high incidence and risk of fires. However, the closed canopy cover afforded by *miombo* communities is thought to provide better protection of watersheds than the patchy canopy of *chipya* species (Lawton pers. comm.). Thus, the maintenance of *miombo* and its extension to more disturbed areas is important for the Park to fulfil its management objectives to preserve *miombo* woodland for protection of slopes and watersheds (LMNP Management Plan 1981). The steep slopes immediately adjacent to the lake should be maintained under *miombo* where possible and should be the main focus of a burning regime within the Park. This is possible only through a controlled burning plan developed in association with the local communities.

Participatory management is vital for the woodlands to meet the needs of both the managing authorities and user groups. While early burns are favoured for the maintenance of *miombo* and to prevent severe late season fires, local communities often prefer later burns that enable them to harvest thatching grass (see Chapter 4). Consultation on temporal and spatial components of the burning regime should enable the dual needs of the Park's authorities and local communities to be met and provide an important initiative in the development of participatory management of LMNP woodlands.

Chapter 6

Temporal change in *miombo* woodland and the impact of local harvesting of woody resources.

Summary

The first part of this chapter explores recent, temporal change in the woodlands through an examination of the vegetation differences between aerial photographs taken in 1982 and 1990. Aerial photographic analysis is used to detect vegetation and land-use change within Lake Malawi National Park (LMNP) and evaluate the efficacy of the protected area for woodland conservation. In the second part of this chapter, vegetation change is interpreted in terms of various biotic and anthropogenic influences. In particular, the impact of local harvesting and use of different woody resources, for both commercial and subsistence purposes, is contrasted.

Part 1: Temporal change to the miombo woodlands of Lake Malawi National Park as measured by aerial photographic analysis.

Introduction

Aerial photographic analysis has been used extensively in the preparation of vegetation and land-use maps. It is a useful technique because large areas can be surveyed rapidly. It is thus convenient for detecting gross changes in vegetation cover and facilitates identification of patterns of land-use change (Goldsmith et al. 1986). Aerial photography has a long history of use in forestry, for vegetation mapping, inventory and management. Forest types and condition classes can be recognised and classified using stereoscopic photo-interpretation to produce vegetation maps (Spurr 1960). It is in this context that aerial photographic analysis is used in this chapter, to detect and monitor changes in LMNP woodland over an eight year period, from 1982 (two years after the establishment of the National Park) until 1990 (the most recent photographs available)[1].

One of the limitations of aerial photographic analysis is that classification of land-use categories is subjective. Analysis relies on the correct interpretation of the tone and texture of the prints, utilising clues such as proximity to settlements and evidence of field boundaries. The scale and quality of the prints, the season, atmospheric interference and the time of day of the photography must be considered for accurate definition of land-use cover. Furthermore, the experience of the interpreter determines the accuracy with which vegetation is assigned to the classification system (Spurr 1960, see below). Familiarity with an area from fieldwork enables more information to be discerned and inferences to be drawn (Ministry of Agriculture 1974). My protracted experience of working in LMNP, together with field verification following interpretation, suggests that this analysis provided both a rapid and accurate assessment of land-use change within LMNP.

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[1] Analysis of older photographs was not possible in Malawi due to a fire which destroyed the aerial photographs held at the Lilongwe Land Husbandry Unit, December 1993.

Methods

Aerial photographs of Nankumba Peninsula, incorporating LMNP, from 1982 (scale 1:25 000) and 1990 (scale 1:40 000) were analysed at the Air Photo Interpretation Unit of the Malawi Land Husbandry Department. Because not all photographs were available, the analysis covers the National Park as centred on Nankumba Peninsula and the three closest islands of Domwe, Thumbi West and Thumbi East. This accounts for over 80 per cent of LMNP and incorporates the Park area under greatest land-use pressure. Stereopairs of aerial photographs were examined systematically using a mirror stereoscope, classifying land-use into the following categories (Ministry of Agriculture 1974):

- sparse woodland (< 50% canopy cover)
- closed canopy woodland (≥50% canopy cover)
- village settlements
- cultivated land (including both wet and dryland cultivation)

Thus, the analysis was based on a physiognomic classification, determined by the extent of canopy cover in wooded areas and the physical appearance for defining settlements and agricultural land. Interpretation was followed by ground verification of areas that proved difficult to classify (1990 series) and discussion with local community members regarding historical land-use (1982 series). The information on the aerial photographs was transferred to two 1:50 000 land-use cover maps, one for each year, to standardise the scales.

Because of the high relief of LMNP, analysis was carried out on the maps prepared from aerial photographs rather than directly from the photographs. This enhances the accuracy because the maps are defined by a known planar projection (Universal Transverse Mercator) and thus the errors due to the variation in scale of the photographs are minimised (Spurr 1960). Here, an area measurement grid overlay was employed to determine the metric area of each land-use class, facilitating a comparison of the extent of each land-use category in each year to be made (Ministry of Agriculture 1974). According to Spurr (1960), the use of such dot grids provide a very rapid and reasonably accurate method of obtaining class areas.

Appraisal of Methods

An error matrix and confidence intervals cannot be placed on the accuracy of the classification because it is not possible to ground truth historical data. However, in producing this classification, I was trained by an experienced interpreter who supervised the analysis of both sets of aerial photographs. The analysis was simplified by using a relatively small number of land-use classes. The woodland categories were necessarily broad because the small scale of the 1990 photos did not allow a more detailed classification of forest cover. This facilitated interpretation because the two different classes of forest cover were easily discerned.

An important source of error in aerial photographic analysis lies in determining the boundaries between different land-use categories. In the present analysis, definition of the boundaries between the two woodland categories was more difficult than determining the limits of either village settlements or agricultural land, the latter being more clearly defined. Given that vegetation is a continuum, positioning the boundary between two vegetation types is necessarily subjective. However, the use of only two forest cover categories reduces the probability of incorrectly identifying areas of vegetation from aerial photographs. Moreover, the use of an experienced interpreter who defined the boundaries for all photographs makes the definition consistent for each set of photographs, albeit subjective (see Trench 1996). Thus, while the scale of the error cannot be determined, it is systematic and this justifies a comparative analysis of the two data sets.

For interpretation of the results, it should be noted that the closed canopy and sparse woodlands of this chapter do not correspond to the *miombo* and *chipya* vegetation described in Chapter 5. While closed canopy woodland is likely to be mature, closed canopy *miombo*, sparse woodland may be comprised of *chipya* type vegetation, a more open *miombo* or a successional stage between the two types.

Results

Figures 1a and b show the land-use cover maps from the 1982 and 1990 analyses of aerial photographs. Table 1 summarises the results of the aerial photographic analysis. It demonstrates that during eight years of management by the Malawi Department of National Parks and Wildlife (MDNPW): the area of cultivated land within LMNP declined by 66.3 per cent, land occupied by village settlements remained stable, the islands retained their closed canopy woodland and the area of sparse woodland within the National Park on Nankumba Peninsula increased by 342 per cent.

Table 1. Monitoring vegetation and land-use change.

Total area analysed: 8222 hectares (ha)
Area of enclave villages (not gazetted within LMNP): 1058 ha
Area of Domwe, Thumbi West and Thumbi East Islands: 578 ha
Area of National Park on Nankumba Peninsula: 6586 ha

Land-use Category	**Total area of each land-use category (hectares)**		**Net Change (%)**	**Area Change as a proportion of total area analysed (%)**
Year of Photographs	**1982**	**1990**	**1982 - 1990**	**1982 - 1990**
Closed canopy woodland[1]	6337.5	5926.0	- 6.5	- 6.2
Total sparse woodland[2]	140.5	621.0	+ 342.0	+ 7.3
Sparse woodland derived from former cropland	/	61.0	/	+ 0.9
Sparse woodland proximal to enclave villages	126.0	393.5	+ 212.3	+ 4.1
Other sparse woodland	14.5	166.5	+1048.3	+ 2.3
Settlements	4.0	4.0	0	0
Cultivated land	104.0	35.0	- 66.3	- 1.1
Closed canopy woodland on islands	578.0	578.0	0	0

[1] The area of closed canopy woodland was deduced by subtracting the areas of all other land-use categories from the measured area of the National Park on Nankumba Peninsula

[2] The total amount of sparse woodland is the sum of the three classes of sparse woodland listed below it.

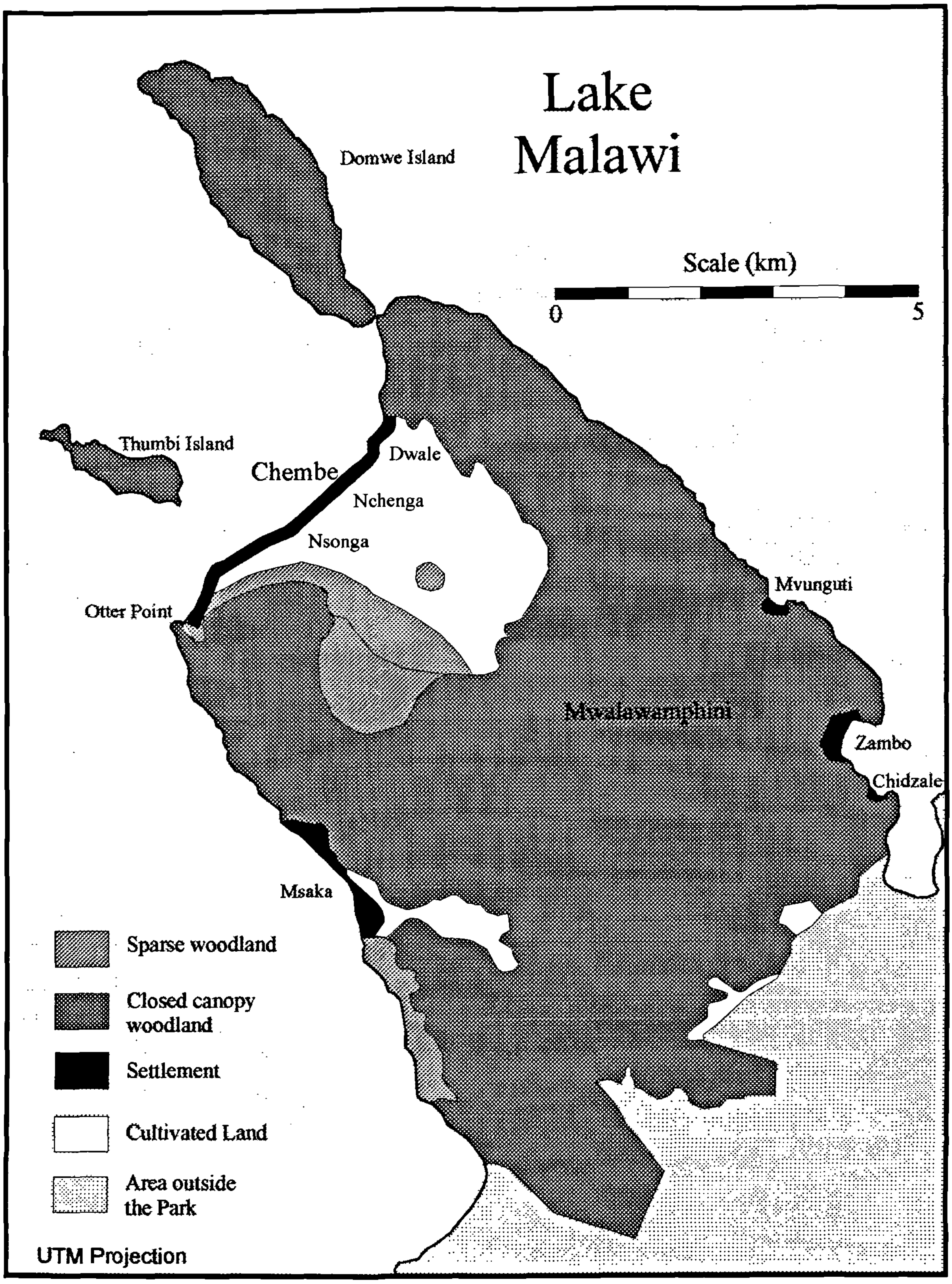


Figure 1A. Land cover classification for LMNP, 1982.

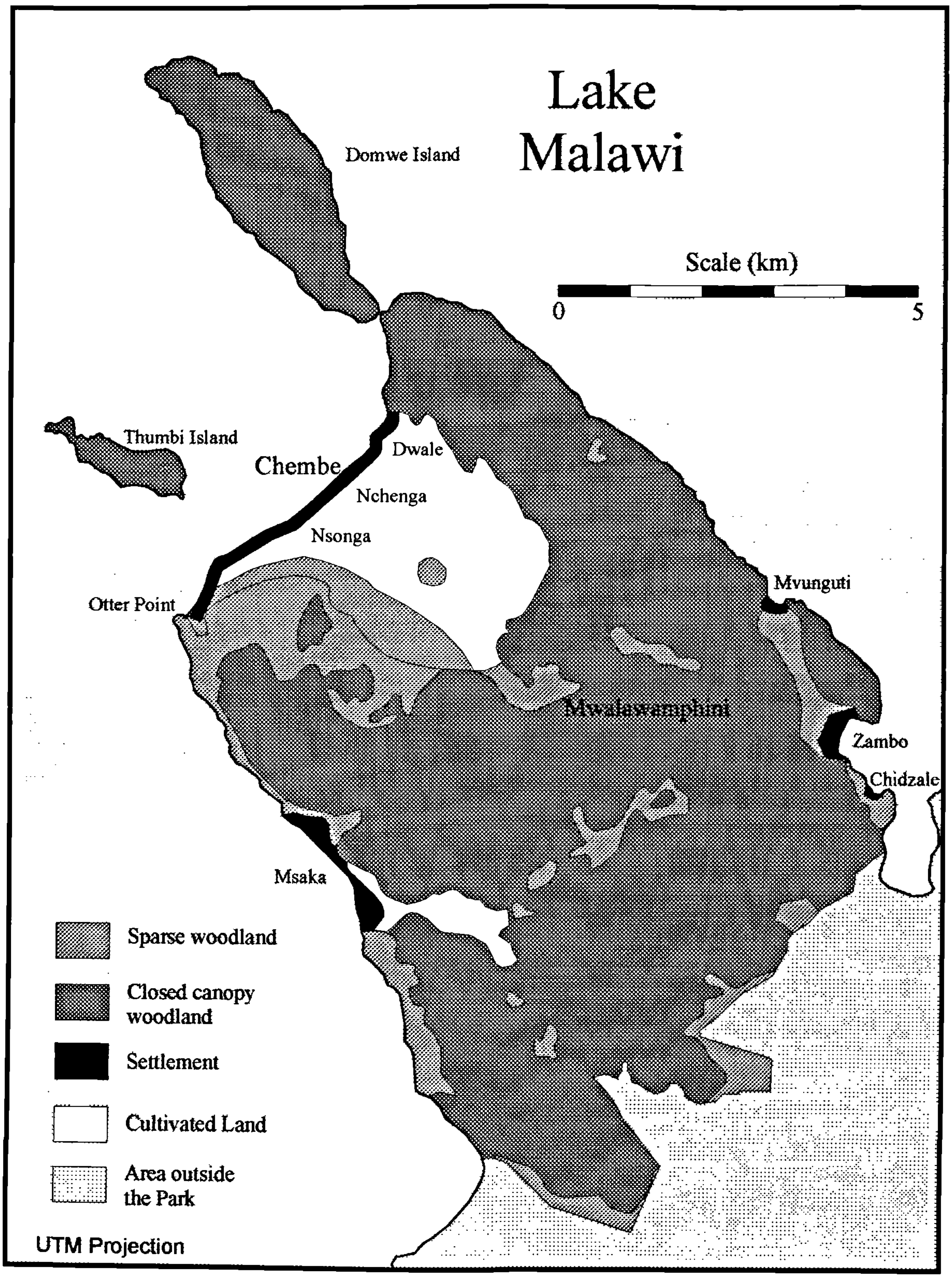


Figure 1B. Land cover classification for LMNP, 1990.

Discussion

Since its establishment in 1980, the MDNPW has had a policy of discouraging cultivation within LMNP. This is reflected in a decrease in cultivated land within the protected area during the period 1982 to 1990. The small area of remaining cropped land is found at the edge of Chembe and Msaka's fields and arises from the equivocal border of the National Park and the enclave villages. The 1990 photographs suggest that formerly cultivated areas within the Park have undergone vegetational succession, with the development of scrubby, sparse woodland communities (see Figures 1a & b).

However, analysis of the 1990 photographs suggests that the increase in sparse woodland since 1982 exceeds the decline in cultivated land over the same period. Given that the area of village settlements has remained stable from 1982 to 1990, the sparse woodland can only be occupying areas previously covered by closed canopy woodland. Thus, sparse woodland may be divided into two types. Firstly, that originating from vegetational succession on formerly cultivated land which has been abandoned. Secondly, that occupying areas of formerly closed canopy woodland. This latter category has been separated into sparse woodland bordering village enclaves and that distributed elsewhere in the Park (see Table 1).

The 1982 aerial photographs indicate low levels of sparse woodland within LMNP, with just over 140 hectares of the area surveyed classified as sparse woodland (Table 1). The rapid expansion in sparse woodland between 1982 and 1990 is a striking observation from the aerial photographic analysis. Excluding that derived from formerly cultivated land, sparse woodland within LMNP on Nankumba Peninsula has increased by 299 per cent in eight years. Furthermore, in 1982, sparse woodland adjacent to the villages accounted for 90 per cent of the occurrence of sparse woodland within LMNP. By 1990, just over 70 per cent of the total sparse woodland is found adjacent to the five village enclaves. The remainder is distributed elsewhere throughout the Park (see Figures 1a & b). The later set of photographs indicate that sparse woodland occurs away from villages, at lower altitude sites (areas such as Mwalawamphini and Otter Point, see Figure 1b).

A number of factors may have contributed to the recent increase in sparse woodland occupying areas of formerly closed canopy woodland in LMNP. These include fire, animal damage and wood cutting practices. In the previous chapter the role of fire in determining the dynamic vegetative patterns of *miombo* was described. Frequent, late fires reduce the canopy cover by preventing regeneration of the fire-sensitive *miombo* canopy dominants and promoting regeneration of the fire-tolerant *chipya* species. Under a late burning regime, *chipya* species tend to replace the turnover in *miombo* standards and form a patchy, rather than closed, canopy. However, an increase in the frequency or severity of fire during this period is unlikely to have caused the observed increase in sparse woodland over an eight year period. The longevity of *miombo* species (see Malaisse 1978) suggests they have a low rate of turnover and thus their replacement in the canopy by *chipya* species is a long term process. Therefore, while fire is an important feature of determining the floristic composition of this woodland, it would appear not to explain the recent canopy cover changes observed from aerial photographic analysis.

Another consideration is animal damage to the woodland. However, as was described in Chapter 2, there are no large mammals within LMNP (the largest herbivore being the klipspringer) whose grazing or browsing could impact upon the vegetation. In particular, elephants, whose destructive influence on *miombo* in Malawi is documented by Jachmann (1984), are absent from the protected area. In some areas of Malawi, where livestock is an important component of the subsistence strategy, cattle grazing within *miombo* affects tree regeneration (see FRIM 1995). However, because of the hot lakeshore climate, no cattle are kept within the villages and thus there is no collection of browse or occurrence of livestock grazing in the Park woodlands. Chembe does contain some goats but these are tethered within the village or farm plots and were never observed in the woodland during the study period. Thus, animal impacts on the Park woodlands are likely to be minimal.

The woodland products harvested by local communities were described in Chapter 4. The Park has a population of 8440 people who depend on the 68 square kilometres of Park woodland for woody products, including fuelwood and construction materials.

The large population of the villages suggests that harvesting of woody materials may have a profound effect on the woodlands. This is assessed in the next section but it is interesting to note that the sparse woodland occurs in areas that are easily accessible to the enclave villages. The occurrence of rings of forest depletion around centres of population, such as rural villages, as here, but also large cities, is well documented (see for example, Myers 1980, Hosier 1984, Whitney 1987). The increase in sparse woodland distributed away from village settlements during the time period studied may indicate that, as forest resources proximate to the enclaves are depleted, villagers are required to access more remote areas of the Park for wood collection.

While villagers may continue to utilise sparse woodland for woody products, the ability of reduced canopy woodland to protect watersheds adequately is uncertain. A negative correlation between vegetation cover and erosion rates is well documented in the literature (see Christiansson 1981, Thornes 1990). Although Bootsma (1987) failed to relate woodland cover to rates of soil erosion within LMNP, he conceded that this may be due, in part, to the difficulty in assessing accurately the extent of erosion over an entire hill slope. He did, however, demonstrate a significant positive relationship between hill slope and rate of soil erosion within the Park, commenting that the susceptibility of the steep slopes to erosion 'highlights the importance of protecting these areas from disturbance through human activity'. Furthermore, as outlined in the previous chapter, Lawton (pers. comm.) suggests that protection of watersheds is best served by *miombo* rather than sparse woodland.

Conclusions

An advantage of aerial photographic analysis is that changes in vegetation cover can be detected, measured and monitored. This analysis has demonstrated the success of LMNP in terminating cultivation within its boundaries. However, it has revealed recent woodland decline in spite of protection within a national park. In the absence of large mammals, this is attributed to a combination of burning and local utilisation of the *miombo* woodland, in particular the extraction of woody products, such as fuelwood and construction poles. The overall net increase in sparse woodland from 1982 to 1990 is large (299 per cent in eight years) but more important than the figure itself, is the pattern of distribution of sparse woodland. The most recent photographs suggest a wider distribution of sparse woodland within the Park than during 1982. One interpretaton of this pattern is that as woodland areas proximate to the enclaves are depleted, villagers begin to exploit the more central areas of the Park, such that formerly less disturbed areas are subject to increased levels of human activity.

Without alternative sources of natural resources, continued community exploitation of the *miombo* woodland is assured. The juxtaposition of the enclave villages and *miombo* woodlands and the absence of a buffer zone facilitate the gradual encroachment of human activity into all areas of the Park. While aerial photographic analysis has highlighted changes in LMNP vegetation cover, it does not establish the specific causes. The second part of this chapter examines local harvesting of woody resources to define the relative contribution different uses of woodland products make to changes in woodland cover.

Part Two: Local patterns of use of woody resources for commercial and subsistence purposes.

Introduction

This section examines patterns of use of woody resources by the two largest villages in LMNP, Chembe and Msaka. It identifies and quantifies the major uses of woody products and describes the size classes and species selected for use within the study villages. Primarily, it seeks to infer the impact of harvesting natural resources on the resource base by exploring patterns of use of forest products.

As outlined in Chapter 1, deforestation has frequently been attributed to domestic fuelwood collection. Simple calculations based on patterns of wood use and *per capita* requirements were used to demonstrate how rapidly forests could disappear through fuelwood collection alone (see, for example, Bell 1978, Myers 1980). However, the reality is more complex. Recent research indicates not all wood collection activities have an equal impact on the woodland (see, for example, Hall and Rogers 1986). Local preferences and patterns of wood selection affect the impact of harvesting on the resource base. While the quantity used is a key factor, this is coupled to the demand for the product, whether from rural or urban populations, or, for subsistence or commercial purposes. Furthermore, it is increasingly recognised that the collection of dead wood and the ability of many tree species to regenerate through coppicing mitigate against the degrading effects of local harvesting practices (World Bank 1991).

The enclave villages of LMNP

Oral testimonies regarding historical patterns of wood use in LMNP were introduced in Chapter 4. Discussion within the villages suggest that fuelwood collection has not always been a problem in the villages: younger women believe that wood collection was less difficult in previous generations, older women maintain that fuelwood was more readily available, closer to the village, when they were younger. The women also expressed a preference for dead wood but have to make long journeys to find it because it is scarce close to the village (see Chapter 9, cf. Grundy et al. 1993).

While women's assertions should be interpreted cautiously because of the selective nature of memory (Slim and Thompson 1993), aerial photographic evidence appears to support oral testimonies. This indicates a recent (during the late 1980s) increase in sparse woodland and a corresponding decline in closed canopy woodland within LMNP (see Part 1). This is consistent with the village consensus that problems with wood collection are relatively recent. Population data from village censuses also support this notion: villages were small and population growth rates in Chembe (for which long term data are available, see Appendix 5) were low until the late 1970s. But Figure 2 indicates that during the intercensal period (1977 - 1987) the population of most of the enclave villages increased dramatically. The latest survey (1994) suggests that the population of most of the villages has since stabilised.

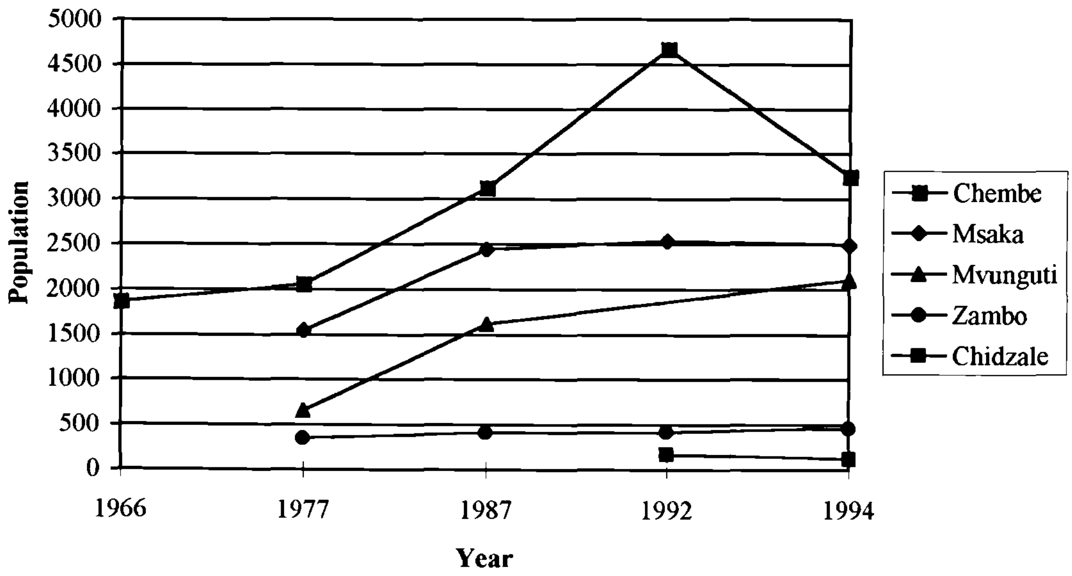


Figure 2. Population change within the enclave villages of LMNP.

Immigration to Chembe may be partially related to an increase in tourism to LMNP during the 1980s (Jalale 1993). This was paralleled by the arrival of people involved in informal tourist service industries and businesses, such as curios sellers (Grenfell 1993). However, the major cause of immigration is attributed to the settling of fishermen from Malawi's Northern Region. Ethnically, these fishermen are mainly of Tonga and Tumbuka origin and were attracted to the productive fisheries found at this shallower, southern end of the Lake (Smith 1993b). During the 1970s, the Northern fishermen took up permanent residence in villages, such as Mvunguti and Zambo, where formerly they had seasonal fishing camps.

Historical accounts of the fisheries and settlement of Nankumba Peninsula are provided by Cole-King (1968) and Smith (1993b). They suggest that prior to the immigration of Northern fishermen, only Chembe and the southern end of Msaka (known as Chimphamba) were settled and by people of Chewa origin. The northern end of Msaka, Mvunguti and Zambo held seasonal fishing camps for the Northern fishermen at this time and became permanently settled during the 1970s. This southern migration of Tonga and Tumbuka fishermen was not specific to Nankumba Peninsula but represents a more general migration south, associated with the depletion of the less productive Northern fisheries (Kapeleta 1980, McCracken 1987).

Village headmen acknowledge that traditional practices of limiting immigration in LMNP, such as allocating land, have broken down. Hence, there are few checks on the growth of the villages, except for the physical amount of space available. The Northern fishermen were allocated the extensive site of Dwale (at the eastern end of Chembe, see Figure 1a) only through a marriage to the daughter of the Chewa chief of Chembe. It appears that only in Zambo, where population growth is minimal, is traditional control still exerted (Grenfell 1993).

Several researchers at LMNP suggest the expanded village populations, and consequent increased demand for domestic fuelwood, are responsible for deforestation in LMNP (Bell 1978, Bootsma 1987, Grenfell 1993). However, other authors (see Dankelman and Davidson 1988, Soussan et al. 1992) suggest that household fuelwood use is not a major cause of deforestation because its collection is selective and piecemeal, rarely involving the felling of trees. The present study examines empirically whether domestic wood collectors are the real or main cause of the decline in woodland cover. To this end, the major uses of wood in the villages (domestic fuelwood, construction materials, and fuelwood used for fishsmoking) are examined. Patterns of wood collection and use are explored for the impact of harvesting on the resource base.

Methods

Household definition and selection

The study was undertaken in two of the villages, Chembe and Msaka, within Lake Malawi National Park (LMNP). In each village, thirty households were selected randomly and asked to participate in the study. The household is defined in terms of a resident kinship group that carries out domestic functions (Bender 1967). Specifically, households consist of an extended family residing within one compound and eating together as a single unit. Households are structured as a fenced compound containing a cooking hut, bathing area and a varying number of separate sleeping huts for different household members.

Following an introductory discussion as to the nature of the project, all the families agreed to be included in monthly household surveys (Casley and Lury 1987). A formalised questionnaire was used to establish household size by identifying and ageing all household members (Oppenheim 1992, see Appendix 6). Subsequently, an inventory of trees growing within the house and farm plot was made. All the trees were identified and their use(s) recorded.

Wood Inventory: Construction Materials

In each of the thirty focal households in Chembe village, the number of poles used in constructing the house and compound were enumerated. Three different types of pole were identified: fencing poles, roofing poles and house supports. For each pole, the species and mid-point diameter were recorded. The durability of the species used for each type of pole was estimated by the head of the household.

Domestic Fuelwood Survey

The fuelwood survey monitored the flow of fuelwood through each of the target households over the same period of seven consecutive days each month. The survey was carried out for twelve months in Chembe village and for five months in Msaka village (due to the loss of a research assistant). On a daily basis, all fuelwood bundles collected or bought by the household, were weighed. In addition, an estimate of the weight of any wood that had been sold or donated (for example, during funerals) to other households was taken.

The schedule of the study was as follows: on the morning of the first day of the monitoring period, the fuelwood stockpile in the household was weighed. Then, daily for seven days, each household was visited in the late afternoon to weigh any fuelwood that had been collected or bought. Most fuelwood collection takes place in the mornings when it is cooler. However, because some women collect in the afternoon, households were visited late in the day to ensure that all fuelwood brought to the household was detected. On the seventh day, the fuelwood stockpile in the household was weighed. This schedule ensured a comprehensive examination of household fuelwood use while making only limited demands on women's time. Generally, the women were happy to participate, readily agreeing to leave bundles tied until they had been weighed by the researcher.

Each month, the woman was asked how many people were residing in the household and her response compared with the original questionnaire survey, identifying household members. This enabled any visitors or absent members of the household to be detected. However, households remained surprisingly stable in terms of the number of residents during the year of study. *Per capita* weekly fuelwood consumption was calculated on a monthly basis. Subsequent analysis of the these data found no significant differences in *per capita* fuelwood consumption between the two villages (Mann Whitney test for two Independent-Samples, 2-tailed $p = .7618$).

Species and size preferences for fuelwood were investigated by dissecting thirty randomly selected fuelwood bundles. To ensure that the complete bundle was examined, bundles were dismantled immediately that women returned to Chembe from a wood collection trip. The number of branches that comprised each bundle was enumerated. For each branch, the species and mid-point diameter were recorded.

Survey of fuelwood in the commercial activity of fish-processing

The wood used by four of the fish-smoking stations in Msaka village was monitored for the same seven consecutive days each month, according to the schedule given under domestic fuelwood above. The species and mid-point diameter of each log were recorded. The weight of wood used was calculated by subtracting the remainder at the end of the week from the sum of the stock pile and the cumulative amount of wood used during the seven day monitoring period. The survey was repeated each month over a period of eleven months.

Wood Collection Tracking

Focal group sampling (Altmann 1974, Gross 1984) was employed to derive time budgets for wood collectors from Chembe village. These data are explored more fully in Chapters 8 and 9. This chapter examines the tools and method of transport used by men and women when collecting fuelwood. On each trip, the tool each person used was recorded: panga[2] knife, saw, axe or stick (sticks were used to knock dead branches out of trees). Individuals who collected wood without tools were recorded as collecting `by hand'. Fuelwood transport methods include: headloading or using bicycles, dug-out canoes and boats.

Production of Dead Wood within Permanent Quadrats

An estimate of the production of dead fallen wood was made using three permanent quadrats (Kent and Coker 1992), each of size 30 m^2. The amount of standing dead wood or 'necromass' was not recorded. This is usually assessed subjectively, using a visual estimate (cf. Shackleton 1993), making the results difficult to interpret. The quadrats were situated subjectively (cf. Shackleton 1993) to reduce the possibility of harvesting by villagers. They were located under closed canopy woodland in relatively inaccessible areas of the Park. Plots were not situated in sparse woodland as this was too accessible to the villages. It should be noted, however, that mature trees (found in closed canopy woodland) produce a greater proportion of dead fallen wood than younger trees, found in sparse woodland (World Bank 1991). Although sparse

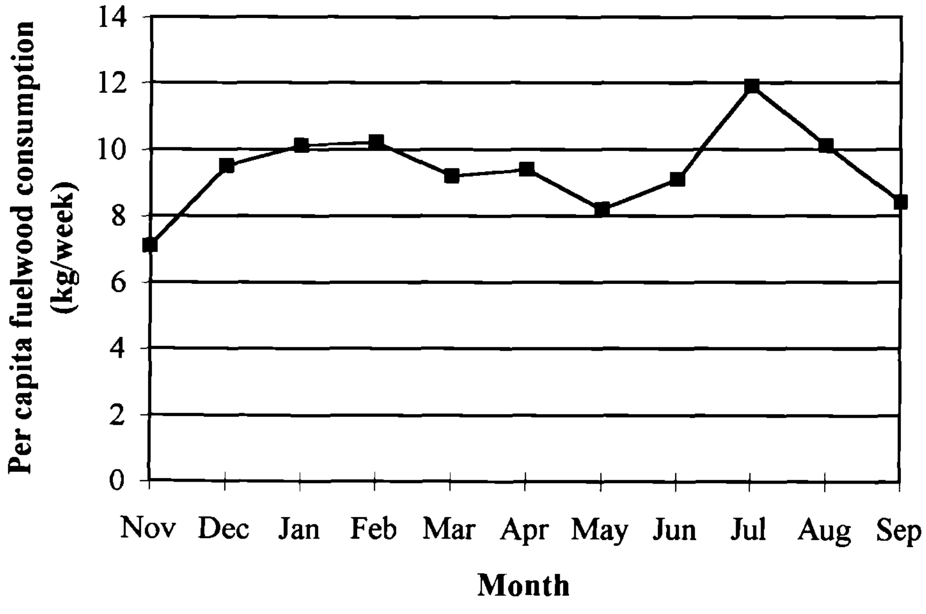
[2] a machete, wide bladed knife.

woodland covers only a small proportion of LMNP (see Section 1), a conservative estimate of the production of fallen dead wood is used in these analyses (see below).

Trees marking the boundaries to each quadrat were clearly paint marked. All the dead wood was removed from the quadrats one month before the survey began to provide a baseline. The village chief requested villagers not to collect wood from the quadrats. On the first day of each month, all the wood on the ground (woody litter), of a size above the utilisation limit for fuelwood, was collected and weighed. The utilisation limit for fuelwood was pre-determined at a mid point diameter of ≥ 2 centimetres. The survey was undertaken each month for a period of nine months.

Analysis and Results

Figure 3 shows the results of systematic monitoring of household domestic fuelwood over a eleven month period. There is no overall significant seasonal pattern in the household use of fuelwood. Tukey's HSD *post hoc* tests (Norusis 1995) indicate the only significant difference in the amount of fuelwood used is between the months of July and November. A discussion of this pattern of fuelwood consumption has been provided previously in Chapter 4. Because there is little seasonality in the domestic fuelwood consumption these analyses use the mean fuelwood consumed per week, averaged across the months for which the surveys were undertaken. Similarly, the quantity of wood used per week for fishsmoking is averaged across the eleven months of the survey. Table 2 contrasts the mean quantities of wood used for construction, domestic fuelwood and fishsmoking.



One Way Anova F = 1.79 p = .0611 NS
Tukey's HSD: Jul is significantly larger than Nov at the 0.05 level

Figure 3. Seasonal variation in fuelwood consumption.

Table 2. Estimated quantities of wood utilised for commercial and subsistence purposes.

Wood Use	Mean Quantity
Domestic Fuelwood: Chembe	10.1 kg per capita per week
Domestic Fuelwood: Msaka	10.2 kg per capita per week
Construction Materials	182 poles per household
Commercial Fuelwood: fish processing	90.1 kg per station per week

An estimate of dead wood production per quadrat, with confidence limits, is given in Table 3. These results are likely to underestimate dead wood production for a number of reasons. Firstly, as the experimental plots were cleared every month, litter may have lost weight between collection periods as the result of leaching, microbial decomposition and feeding by animals (see Malaisse et al. 1975). Secondly, it is probable that some harvesting of fuelwood was undertaken by villagers, despite the quadrats being situated in more remote areas of the Park and the Chief requesting people not to collect wood from within marked plots.

The three quadrats covered a total survey area 2700 m^2. The results are extrapolated to estimate the mean production of dead wood within LMNP on Nankumba Peninsula, but excludes the islands which are not accessible to the enclave villagers. It also assumes uniform dead wood production across the peninsula. Because the plots were placed in closed canopy woodland, the calculation may over-estimate total production because the peninsula incorporates areas of sparse woodland. Although this may be negated by local harvesting within the plots, the lower confidence interval is used in these analyses, to provide a conservative estimate of the production of dead fallen wood.

Table 3. Production of dead wood on Nankumba Peninsula compared with estimated domestic fuelwood consumption in the five enclave villages.

Parameter	Mean	95 % Confidence Intervals
Deadwood produced per 30m^2 quadrat per month	11.5 kg	6.2 - 16.6 kg
Estimated deadwood produced on Nankumba peninsula *per annum* [1]	10,530,933 kg	5,677,547 - 15,201,173 kg
Estimated fuelwood consumed by the five villages *per annum* [2]	4,432,688 kg	3,993,808 - 4,950,566 kg

[1] Area of Nankumba Peninsula covered by LMNP is 68.7 km^2, excluding the islands
[2] Assumes a total population of 8440 people (see Appendix 5) consuming 10.1 kg per person per week

Tables 4 and 5 detail, respectively, the size class and species preferences for woody resources used within the village. Table 6 documents the number and ownership (by cultural group) of fishsmoking stations within the five enclave villages.

Table 4. Size class preferences for woody products together with their estimated durability.

Wood use	**Mean mid point diameter/cm**	**Size Class[1]**	**Durability/years[2]**
Fuelwood: domestic	3.6	1	/
Fencing pole	3.4	1	12.5
Roofing pole	3.2	1	14.3
House supports	4.9	1	12.2
Fuelwood: fishsmoking	23.8	5	/

[1] See Appendix 7 for explanation of size classes
[2] Durability depends upon the species used, the figure displayed is the average durability combined across all species encountered.

Table 5. Species selection.

Wood Use	**No. species encountered**	**Species most frequently used**	**% most frequently used species was encountered**
Fuelwood: domestic	28	Brachystegia microphylla	40.9 %
Fencing pole	15	Commiphora africana	18.6 %
Roofing pole	19	Markhamia acuminata	23.7 %
House supports	15	Bridelia spp.	34.2 %
Fuelwood: fishsmoking	14	Brachystegia microphylla	56.9 %

Table 6. Ownership of fishsmoking stations within the villages, by cultural group.

Village	**Northern Cultural Group (Tonga or Tumbuka)**	**Southern Cultural Group (Chewa, Yao or Lomwe)**
Chembe: Nsonga and Nchenga	0	6
Chembe: Dwale	35	37
Msaka	31	16
Mvunguti	86	30
Zambo	42	3
Chidzale	19	0
Total	**213**	**92**

Discussion

The Discussion is divided into three sections. The first considers the impact of domestic fuelwood collection on the *miombo* woodlands. The second examines the collection and use of woody resources for construction purposes. The final section explores the fuelwood used in the commercial activity of fishsmoking. A discussion integrates the findings from all three sections in the context of the current literature.

Domestic Fuelwood

Woodland decline may be studied in terms of its effect on human resources (Brouwer et al. 1989, Dankelman and Davidson 1988). In LMNP, as in the rest of Malawi and many developing countries (Spring 1988), women are the regular collectors of domestic fuelwood. Tracking female wood collectors demonstrates that fuelwood collection trips average four hours duration (see Chapter 8). Increased time and energy spent in wood collection is one of the coping strategies employed by women facing fuelwood shortages (Brouwer et al. 1989).

The results from monitoring household use of fuelwood indicate that each villager consumes substantial quantities of fuelwood, approximately 10 kg of fuelwood per person, per week (Table 2). Hence, the estimated annual consumption of fuelwood in the enclave villages is similarly large (Table 3). These results appear to support the hypothesis that domestic fuelwood collection would have a substantial impact on woodland communities.

However, Chapter 4 emphasised that village women prefer dead wood as an energy source, because of its ease of collection and superior burning properties compared with live wood (see also Shackleton 1993). Table 3 contrasts the estimated annual production of dead wood in LMNP on Nankumba Peninsula with annual fuelwood consumption. These results indicate that large quantities of dead wood are produced within the woodland. The production of dead wood exceeds consumption, even when using a conservative estimate of dead wood production (the lower confidence interval) and the upper confidence interval to estimate consumption. These findings suggest that, provided villagers express their preference for dead wood, the *miombo* woodland can support high levels of fuelwood harvesting. Specifically, it is estimated that the deadwood produced in just 69 hectares of woodland could support the fuelwood requirements of the total population of 8440 people living in the Park. It should be noted that the deadwood production estimate is for the whole Park, yet women's wood collection activites are concentrated in woodland areas proximal to the village. This suggests that highly frequented woodland areas would be depleted of dead wood, with more dead wood available in less accessible areas. This was observed in LMNP and has been measured by Grundy et al. (1993) in their study of resettlement areas in Zimbabwe. They found that the amount of dead wood that could be collected for fuel in the woodland was greatly reduced in the immediate vicinity of settlements.

While the consumption of dead *versus* live wood was not measured in this study, other research indicates local preferences for dead wood as an energy source. Working in the Sudan, Whitney (1987) suggests that 'in rural areas most of the fuelwood comes from dead branches, and ... only 10 percent of the rural firewood used involves the destruction of entire trees'. Similarly, the World Bank (1991) estimate that, in many rural areas, dead wood may represent over 80 percent of the woodfuel collected by villagers. Shackleton (1993) investigated fuelwood harvesting in a communal grazing land and a protected area in the Eastern Transvaal Lowveld. He demonstrated that the amount and size class of dead wood at the harvested site was significantly reduced, reflecting people expressing their preference for this resource.

Clearly, deadwood is an important component of both domestic energy and woodland production. The World Bank (1991) estimates that deadwood accounts for 30 - 50 percent of the gross mean annual increment of forest trees. Such wood is the result of natural forest mortality, branch pruning or the effect of winds. Collection of deadwood is alleged to be of low environmental impact because it precludes the destruction of live trees. In temperate regions, however, the importance of deadwood (either standing or as litter) for woodland cycling, promoting soil fertility and slowing erosion on hillsides is noted (Ackerman 1993). Deadwood is also important for bird and invertebrate communities and increases woodland diversity by offering specialised ecological niches. Notwithstanding the ecological significance of dead wood, its harvesting has less of an environmental impact than the cutting of live wood. Thus, in these analyses, the harvesting of dead wood by villagers is assumed to be environmentally sustainable.

These results suggest the *miombo* woodlands provide sufficient *quantity* of dead wood for the enclave villages if women select dead wood to make their bundles. However, this analysis does not incorporate the *quality* of the dead wood produced. Tables 4 and 5, respectively, indicate the size and species preferences for domestic fuelwood. The mean mid-point diameter of the domestic fuelwood selected was small, less than 4 centimetres. Women also select a wide range of species, 28 different species were recorded in the thirty bundles that were analysed i.e. women used nearly one third of the species recorded in the vegetation survey (see Chapter 5). One hardwood species, the canopy dominant, *Brachystegia microphylla,* is preferred and used most frequently.

Women contend they use a range of species and size classes because different woods have different purposes. For example, small, fast-burning woods are used to start fires while larger, slow-burning species maintain fires for cooking purposes. Furthermore, because women headload their bundles, they select a variety of fuelwood species, a trade-off between preferred hardwoods which are heavy to carry and lighter species which are less efficient fuelwoods (Abbot 1993). Wood preferences are thought to influence patterns of wood collection in the Park. This is considered in Chapter 9.

While the quality of collected firewood was documented, the quality of the dead wood produced, in terms of size or species, was not recorded. The experimental plots measured only the quantity of fuelwood above the utilisation limit. It was observed, however, that the dead wood consisted primarily of branches of small mid-point diameter, rather than large logs or trunks of fallen trees (cf. Shackleton 1993). The extent to which preferences for specific fuelwood species and size classes can be met, in a wood collection trip to one area of the woodland, is not known. It would seem unlikely, however, that bundles of the appropriate quality could be compiled entirely of dead wood, especially in the more frequented areas of the woodland, close to the village. Thus, women are likely to cut some live wood to make their bundles of sufficient quality. This is consistent with my observations that bundles comprised both dead and live wood.

The collection of a combination of dead and live wood will not necessarily have a discernible, negative impact on woodland communities. The sustainable offtake of fuelwood is much higher than just the production of deadwood. Shackleton (1993) assumes that 3 percent of standing crop is a sustainable yield. But this disregards the high growth rates of coppiced species (see below), implying that sustainable yields from natural woodland could be even higher. To monitor the impact of cutting of live wood on coppicing and woodland regrowth requires a long term study and was beyond the scope of this research. However, the management of *miombo* by local communities, sustainable rates of wood cutting and coppice rotations are the subjects of a three year study currently undertaken in various protected areas in Malawi (FRIM 1995). Other studies in Zambia examine *miombo* biomass and have developed site specific regression equations to predict fuelwood production and yield from simple forestry measures of tree height, diameter at breast height etc. (see Stromgaard 1985b, 1986a, Chidumayo 1987a, 1988a). The applicability of these models to sites elsewhere has yet to be demonstrated.

A final point in the use of domestic wood is the tools available for fuelwood collection. By tracking wood collectors, it was possible to detail the tools used and determine how women collect firewood. Figure 4 suggests that women wood collectors have only limited tools for obtaining fuelwood: most collect by hand or with a panga knife. Sticks are also used, to dislodge dead branches still attached to the tree. My observations suggest that more dead wood (both standing and fallen) than live wood is gathered by women who collect by hand or with sticks, since they lack the tools required to cut live wood of a substantial size.

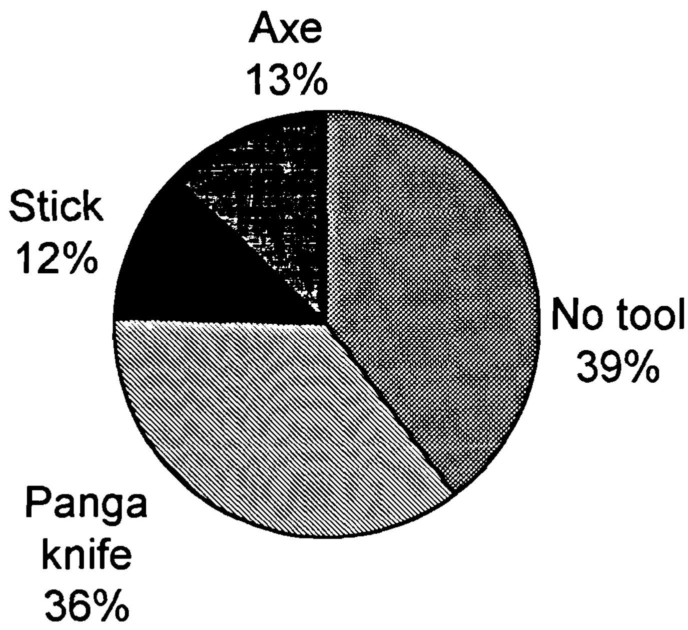


Figure 4. Tools used by the observed domestic wood collectors.
(n = 72 women, no woman had more than one implement).

The increase in sparse woodland from 1982 to 1990 (see Section 1) implies the felling or loss of canopy trees. Yet Figure 4 indicates that only 13 percent of women have tools, such as axes, suitable for felling trees. No trees were felled during the wood collection trips when women were tracked, although this may be an artefact of being observed. Much of the gathered wood was dead, although live wood was collected using panga knives or by breaking small branches. The tools available to most women suggest they are able only to cut small wood. This corroborates the findings in Table 2 indicating selection of fuelwood of a small mid-point diameter. Furthermore, because all domestic fuelwood is headloaded, the women assert that large logs are heavy to transport and preclude the transport of a range of different species.

These patterns of resource collection support the hypothesis that domestic wood collectors cannot be the only, or major, cause of the recent increase in closed canopy woodland. Women lack the tools required to fell trees and because they headload fuelwood, are limited in the amount of wood they can carry. Species selection is broad, encompassing almost one third of recorded tree species. The selected branches are of small mid-point diameter, a convenient size to cut, carry and utilise within the household. Furthermore, the estimate for the production of dead wood suggests that this preferred resource can meet the domestic fuelwood requirements of the enclave villages. In areas where dead wood is exhausted or of insufficient quality to be used as fuelwood, live wood may also be used.

There are two main caveats in this analysis. Firstly, the data on the production of dead wood should be interpreted with caution. The availability of dead wood does not mean that women use dead wood, or use it exclusively. However, because dead wood is easier to harvest than live wood, it is not unreasonable to assume that women use this resource where it is available. Secondly, the findings do not imply that domestic fuelwood collection has no impact on the woodlands. Rather, they demonstrate that patterns of wood collection and preferences are important factors that determine the sustainability of resource use. Specifically, this study has demonstrated that the production of dead wood is substantial (cf. World Bank 1991) and may mitigate against the assumed damaging impact of domestic fuelwood collection. Thus, it appears that the women in LMNP are unlikely to be responsible for the marked and recent decline in woodland canopy cover as illustrated by aerial photographic analysis.

Construction materials

The enclave villagers collect poles from the *miombo* woodland for house and fence construction. The results from measuring thirty houses in Chembe indicate poles of small size classes are preferred (Table 4), although larger poles are selected for house supports (upholding the roof) than for fencing or roofing purposes. While large numbers of stems are used in house construction, these items have extended durability (Table 2). Poles are selected from a wide species base, with no single species dominating (Table 5).

The effects of cutting young, live poles on woodland communities are unknown. There is only a limited literature documenting the internal changes in forest structure and composition that accompany wood collection by rural communities (see Hall and

Rogers 1986). Thus, it is difficult to assess the sustainability of wood collection in the absence of data on how woodlands respond to selective collection of woody resources. Studies on primary production ecology are available (see review by Rutherford 1979). But there are many problems with applying these to the local harvesting of woody products, primarily because they are not linked to use patterns. For example, data on total woody biomass are useful if the woodland is to be clearfelled, which is not the pattern of local harvesting practices. Furthermore, where studies have documented the volume or increment of specific trees, the species investigated have been selected for their timber potential and may differ from trees considered locally as important sources of forest products.

Conflicting and insufficient data document the impact of local cutting practices on woodland communities. However, the important role of vegetative reproduction, or 'coppicing' from the stumps and root masses of felled trees is increasingly recognised (see Stromgaard 1986b, Nyerges 1989). In an early study and reporting preliminary findings, Hall and Rogers (1988) caution that while many species may respond to cutting by coppicing, repeated cutting may weaken coppice stools. Repeated coppicing of canopy and emergent species may prevent them from reaching full stature and hence reproductive phase. This may cause long term changes in canopy structure and diversity. Similarly, in a study of human induced changes to succession on the Rhodesian (*sic*) highveld, Strang (1974) found a down-grading of heavily cut woodland sites to shrub savanna. The continued felling of pole-sized trees and saplings resulted in an unbalanced size-class distribution, with an excess of larger old trees and inadequate recruitment of smaller stems.

By contrast, more recent studies suggest that coppicing facilitates woodland recovery, increases productivity and compensates for local cutting pressures. Shackleton (1993) investigated harvesting in a communal grazing land and a protected area in the Eastern Transvaal Lowveld. He found standing crop was little altered at the communal grazing land despite several decades of wood collection, which he attributes, in part, to rapid coppice regrowth following harvesting. This finding demonstrates that the regeneration capacity of harvested woodland remains strong, despite several decades of exploitation.

From his study of regrowth *miombo* in Zambia, Chidumayo (1993) also demonstrates the rapid growth of wood in the coppice. He noted that the coppicing ability of many species ensures fairly rapid recovery following cutting and enhances woodland productivity through an increase in tree density. Similarly, Grundy (1993) documents the regeneration of *Brachystegia spiciformis* and *Julbernardia globiflora*, two dominants of Zimbabwean woodland that are important construction species. She shows that both species show rapid initial increases in growth after cutting, although the impact on the woodland community of harvesting these key species is not documented.

During the gazettement of LMNP, Bell (1978) made a bleak prediction for the *miombo* woodlands. Based on crude estimates of wood consumption within the enclave villages, he predicted that a wood crisis would occur within 30 years. Whilst his calculations were somewhat 'political' in their use to establish a National Park in the area (Bell pers. comm.), he attributes the failure of his forecast to underestimation of coppice regrowth in LMNP woodlands.

It should be noted that the intensity of cutting will determine the extent to which standing crop will be altered. While large numbers of poles are used in the villages, the extended durability of construction materials suggests that their collection is unlikely to cause the marked woodland decline, highlighted by the aerial photographic analysis. Furthermore, the use of *Eucalyptus* spp. grown within the village enclaves (an acceptable alternative to *miombo* species) reduces village dependence on the Park's natural resources. For example, among the 30 focal households, 47 per cent grew *Eucalyptus* spp. within the household and 30 per cent grew *Eucalyptus* spp. within farmplots. This species is preferred because of its rapid growth and coppicing ability. Furthermore, the poles of many *miombo* species (e.g. *Commiphora africana* and *Lannea discolor*) take root and grow to form live fences (see Coates Palgrave 1983): 63 per cent of the focal households had fences that contained live poles. These reduce the need for further pole collection.

In summary, the absence of studies measuring the regeneration of locally important woodland species impedes an accurate assessment of the impact of pole cutting. The studies reviewed above suggest that wood cutting may reduce species richness (Shackleton 1993) and alter the size class distributions of woodland, resulting in a woodland with a high proportion of large trees and smaller stems. Although pole cutting may alter woodland structure, the ability of many species to regenerate through coppicing appears to reduce the impact of cutting practices on the resource base. The reduction in closed canopy woodland is attributed to selection of large-sized canopy species rather than the cutting of small sized, understorey trees poles for village construction purposes. Thus, while pole cutting may have long term effects on woodland diversity and structure, it is not thought to have caused the marked degradation of closed canopy woodland to sparse woodland.

Fuelwood used in fishsmoking

A less obvious but major use of wood in the village, is fishsmoking. Large fish are conventionally smoked at open wire smoking places. This preserves the fish, both to increase domestic shelf life and allow transportation to markets. Fish processors require wood to burn for a long time without producing much smoke. Hardwood species are preferred because they produce '*makala*' or coals that retain heat. Large logs of wood are selected which burn for prolonged periods, without the fire going out (Abbot 1993).

Data from monitoring four fish smoking stations at Msaka demonstrate this preference for wood of a very large size class. On average, the logs have a midpoint diameter six times larger than the average piece of fuelwood selected for domestic purposes (Table 4). Species selection is narrow. Nearly two-thirds of the logs monitored consisted of just one species, the dominant, hardwood canopy tree, *Brachystegia microphylla* (Table 5). This activity is highly species specific, in total just fifteen different species were recorded at four fish smoking stations during the eleven month monitoring period.

Fishsmoking is usually carried out by men and the wood is collected by them. Wood of the preferred, large size class is obtained from trunks or very large branches. The former requires the tree to be felled because the natural turnover rates for hardwood species of suitable size are insufficient to meet the demand for fish processing (see Malaisse 1978). No fallen trees and few large branches were encountered in the experimental plots measuring fallen dead wood (cf. Shackleton 1993).

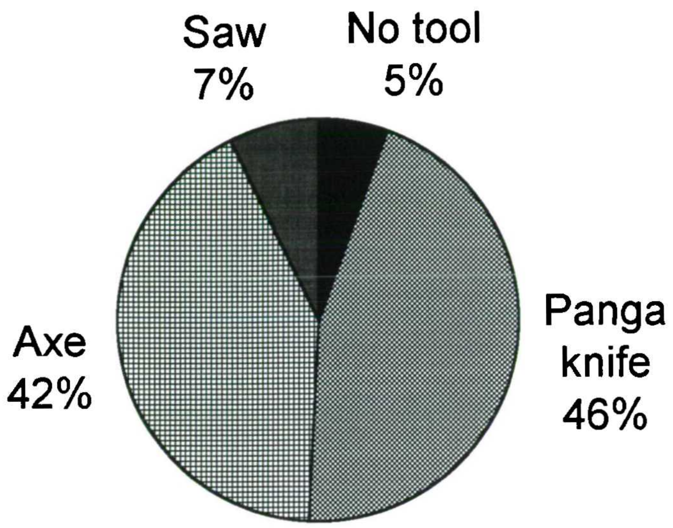


Figure 5. Tools used by men while collecting wood for fishsmoking.
(n = 19, each man may use more than one implement).

Figure 5 indicates the wood collection tools used by male wood collectors. By contrast to women, men have the tools (axes and saws) that are required to fell trees. Whereas most women collect by hand, just 5 per cent of men collected in this fashion. The vast majority had panga knives and/or axes. A small number had saws which improve their efficiency of wood cutting. In addition, men used boats, dugout canoes and bicycles to aid transportation of their heavy loads (Figure 6). Only one fifth of men collected wood on foot but this was the sole method of transporting fuelwood available to domestic fuelwood collectors.

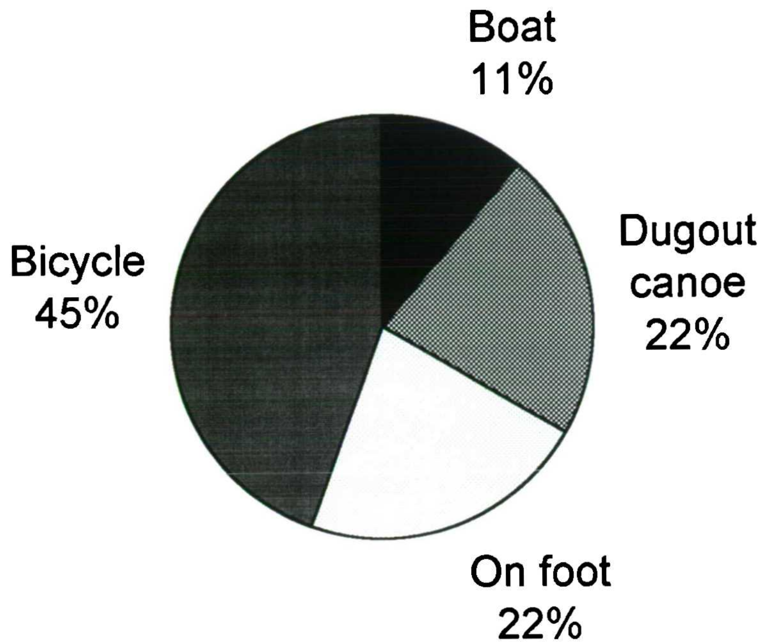


Figure 6. Transportation for men observed collecting fuelwood for fishsmoking (n=27).

The large quantities of wood required to smoke fish (Table 2), support the hypothesis that this commercial enterprise would have a major effect on the Park woodlands. Open wire fishsmoking places have a high fuelwood consumption: trials around Lakes Chilwa and Chiuta, Malawi, suggest approximately 1 kg of wood is required to smoke 1 kg of fish (Walter 1988, Wilson 1992). Moreover, the large size of the wood selected suggests that harvesting would have a direct effect on the woodland canopy. In her study of Tana River National Primate Reserve, Kenya, Medley (1993) suggests that the removal of large trees leaves a gap in and opens up the forest canopy. This is consistent with the pattern of change observed in the aerial photographs suggesting the removal of mature, canopy trees. In addition, the number of fish smoking stations in each village (Table 6) illustrates the great pressure that fish processing puts on the Park woodlands. While large quantities of dead wood are produced in the woodlands, the narrow species diversity and large size of fuelwood used in fish processing limit the usefulness of this resource to fishsmokers.

The historical pattern of fish processing may be explained through examination of trends in local fishing gears (Smith 1993b). The open-water seine net ('chilimira') dominates the Chembe fishery, catching mainly *usipa* (*Engraulicyprus sardella*) and *utaka* (*Copadichromis* spp.). These fish are sufficiently small to be sundried for preservation. Another commonly used type of net is the gillnet (Smith 1993a). This catches larger fish (for example, *kampango, Bagrus* spp.) which require smoking for preservation.

Fishsmoking is an important commercial enterprise in most of the enclave villages, but appears to be a relatively new phenomenon. Bertram et al. (1942, in Smith 1993a) made the first detailed study of Lake Malawi's fish and found a 'few' gillnets in Chembe in 1939, but this was not a common fishing gear used at the time. Bell (1978) questioned 1858 and 520 people in Chembe and Msaka and found that 73 per cent and 82 per cent of people respectively, used no wood for fish processing. This was attributed to sun-drying of the primary catches of *usipa* and *utaka* fish. Bell (1978) reports that gillnets were found mainly on settlements on Maleri and Mumbo Islands where fuelwood was utilised for preserving the catch.

Smith (1993b) attributes the increase in gillnet fishing, and thus the increase in fish smoking to aid preservation, to the recent immigration of the Northern Tumbuka and Tonga people. These people settled in Dwale (Chembe), Msaka, Mvunguti and Zambo villages where they introduced and expanded gillnet fishing. Smith (1993b) reports that half of all gillnet fishing at Chembe is undertaken by the few Northerners who live at Dwale, the easternmost part of Chembe (see Figure 1a). Table 6 demonstrates that fish smoking is now widespread among the enclave villages but is primarily undertaken by people of Northern origin. The Northerners also boil small fish, such as *usipa*, before sun-drying, thus adding a wood-dependent processing stage, which is not used by the Chewa people. Recent, yet extensive, use of wood for fish processing, is consistent with aerial photographic evidence demonstrating significant woodland decline in the late 1980s.

The Chewa traditionally sun-dry their fish. Thus, low levels of fish smoking are found in the Nsonga and Nchenga parishes in Chembe. Furthermore, the increase in tourism to Cape Maclear LMNP, has expanded the market for large, fresh fish (such as *kampango*), thereby eliminating the need for any fish processing. Much of this fresh fish originates from fishermen from the proximate parishes of Nchenga and Nsonga.

These historical patterns of settlement suggest that fishermen from the Northern region expanded the use of gill nets, and consequently fishsmoking, on the Nankumba Peninsula. The improved fishing technologies introduced by the Tonga and Tumbuka fishermen initiated a change from a subsistence to commercial fishery. These technologies have spread within the villages and currently nearly one third of the owners of fishsmoking stations have southern origins (see Table 6).

The Chewa often assert that the Tonga and Tumbuka fishermen may have only short term interests in the Park's natural resources because they will eventually return to the Northern region. They believe that this leads them to degrade the environment and be less inclined towards sustainable woodland management. This implies that the Chewa, as permanent residents, are more interested in the long term conservation of the natural resources of LMNP. Fairhead and Leach (1995a) suggest that it is often convenient to blame migrant communities for ir-responsible resource use and environmental damage. However, this study suggests that it is not the temporal view of the resource nor the culture *per se* that affects its use. Rather, it is the activities (i.e. gillnetting and wood-dependent fish processing) introduced by, and associated with, one culture more than another, that affects resource use. Therefore, the present study does not isolate a culture but a commercial activity that appears to have a severe impact on the woodland environment.

Preservation of the large catches enable fish to be transported and sold in inland markets. Fish is a major source of protein in Malawi and most of those landed in the villages are sold in urban centres, either by the fishermen directly or by fish traders (see Chapter 4). Only a small proportion of landed fish are consumed in the village. This appears to be a common pattern amongst small scale fishing communities around the world (Mitchison 1986). While the economics of the fish trade are explored further in Chapter 7, the present study indicates the substantial quantities of wood used to support this commercial enterprise, which depends entirely on the extraction of natural resources.

A summary of the harvesting of woody products from LMNP

The findings of the present study suggest that the demand for woody resources plays an important role in determining the impact of its collection. Rural communities harvesting wood for local, subsistence purposes appear to have a lower environmental impact than wood harvested for commercial purposes or to service urban demands. Whitney (1987), for example, makes a distinction between the impact of urban and rural demands for fuelwood on woodland communities in the Sudan: the *per capita* impact of firewood cutting on deforestation is more severe in urban than rural areas. He attributes this to the clear-cutting of woodlands for the commercial supply of firewood and charcoal to urban centres. Chidumayo (1987a, b, 1993) similarly demonstrates woodland destruction for charcoal production for the urban market in Zambia. Ravindranath et al. (1991) show the impact of urban fuel demand on tree biomass in India. They demonstrate depletion of village tree biomass largely for export to urban areas: 76.1 per cent of the total biomass felled during the two year study period was sold to traders in nearby towns. Furthermore, Hall and Rogers (1988) note the effect of pitsawing timber, which is for commercial, rather than local, use. A large number of stems are cut indiscriminately to support the felling and sawing of the target timber trees. They estimate a combined destructive impact on about 0.25 hectares for a removal of about 30 cubic metres of wood. Hence pit sawing causes local pockets of high density pole cutting.

Similarly, the present study suggests that a commercial venture, founded on a high level of urban demand for the product, fish protein, precipitates local woodland degradation through the use of fuelwood to preserve the fish. As outlined previously, open wire fishsmoking places have a high fuelwood consumption. Fish processing requiring wood appears to have escalated recently, co-incident with the expansion of village populations and the residency of Northern Tumbuka and Tonga fishing families. The results suggest that wood collection for fishsmoking has a major impact on the woodland communities because the preferred species and large size class of wood requires felling large, canopy trees. The men who undertake this activity have access the tools to fell trees and the transport to carry their heavy loads to the villages. The increase in fish catches that require processing appear to be concurrent with the decline in forest canopy.

The patterns of collection and use of wood for local, subsistence purposes are quite different from those used for the harvesting of fuelwood for fishsmoking. However, the impact of rural wood collection clearly depends on the size of the community. Where populations and wood demand are large, offtake rates may exceed what is sustainable. Preferred species and size classes may be over exploited and a wider range of trees harvested. This may ultimately result in woodland degradation. Thus, while domestic demand for fuelwood and construction materials are not without impact on the LMNP woodlands, the preferred size classes and methods of collection do not necessitate the felling of large, canopy tree species. Furthermore, the production of deadwood is thought to contribute substantially to domestic fuelwood and cultivation of poles within the village reduce dependence on the woodland for construction materials. It is therefore postulated that commercial enterprises appear to be the major force changing the structure of, and canopy afforded by, LMNP woodlands.

Conclusions to Parts 1 and 2

The present study has investigated the status of the LMNP woodlands in combination with the use of woodland products in the enclave villages. Woody resources are extracted for use as domestic fuelwood, for construction materials and, commercially, for fishsmoking. Because of the large village populations, these activities appear to be detrimental to the woodland, reducing mature, closed canopy woodland to sparse woodland. Reduced canopy woodland is thought to have a decreased capacity to protect watersheds adequately and prevent soil erosion. Woodland degradation also reduces the Park's aesthetic value, a prime factor in tourist attraction (cf. Emerton 1995a).

This research demonstrates that not all wood collection activities have an equal impact on the woodlands of LMNP. In spite of their conspicuous collection patterns domestic wood collectors (mainly women), are thought to have limited destructive powers on the woodland because: they prefer dead wood and small sized branches, their species selection is broad and flexible, and since most women lack the tools required for felling trees, they lop live branches to compile their bundles. Wood cutting for building materials appears to have a similarly limited impact on woodland communities. Because of the extended durability of poles selected for fencing and house construction, their collection is not a regular activity. Species selection for this purpose is broad and the use of fast-growing exotics (such as *Eucalyptus* spp.) reduces village dependence on the Park woodlands.

However, wood used in the commercial activity of fish processing is of narrow species base and biased towards large size classes, which require felling of the tree. The gap caused by felling the canopy tree is likely to favour regeneration by shade intolerant *chipya* species rather than *miombo* species. *Chipya* species flourish under the conditions of high light intensity that are created by removal of the canopy dominant. However, under an appropriate burning regime, *miombo* species may be able to re-establish themselves under the patchy canopy formed by the *chipya* standards.

Large quantities of fuelwood are used at each fishsmoking station because the fishermen use open-wire smoking stations rather than the more fuel-efficient fishsmoking kilns (see Appendix 14). Furthermore, the men who collect the fuelwood for this activity have access to the tools to fell trees and the transport required to return heavy loads to the villages. Thus, wood selected for fish smoking is thought to be the major factor contributing to the increase in sparse woodland in LMNP as demonstrated by aerial photographic analysis. The present study suggests that it is a commercial activity, with an urban demand for the fish product, that drives the decline in closed canopy woodland within LMNP. This is consistent with other reserach findings, outlined previously, that demonstrate that the end-use of, and demand for, the product are key determinants of offtake.

By detailing various wood cutting practices that impact upon the woodlands of LMNP, this study provides a basis for informed management policies by the MDNPW. These should focus on methods of reducing demand for, and providing alternative sources of, woody biomass within the enclave villages (see Appendix 14). In addition, law enforcement (see Chapter 9) and community extension efforts should be shifted in emphasis to address what appears to be the most damaging form of wood use, the selection of fuelwood for fish processing. This chapter has highlighted the fallacy of making rapid assessments of the impact of harvesting practices and supposed causes of deforestation. This interdisciplinary study has enabled the causes and effects of resource use to be explored by taking a local level approach to resource use.

Chapter 7

The economic potential for trade in natural resources harvested from the *miombo* woodlands of Lake Malawi National Park.

Summary

This chapter examines the potential for local trade in non-timber forest products (NTFPs) harvested from the *miombo* woodlands of Lake Malawi National Park (LMNP). The range of NTFPs that are utilised locally were described in Chapter 4. This chapter takes an economic approach to resource use and tests the viability of trade in NTFPs for local people. Currently, few NTFPs are marketed outside the village. In the context of current thinking to enhance the role of communities in conservation, this study examines the feasibility of extractive reserves, using LMNP as a case-study. Extractive reserves are protected areas with the dual role of conserving natural resources and developing economic activities based on the sustainable resource harvesting. Local marketing of NTFPs is an important, yet neglected, area of forestry research. Networks and patterns of NTFP marketing are highly uncertain, and the constraints and opportunities faced by market traders ill-defined (Padoch 1992). Thus, this research takes a local-level perspective, analysing the costs and benefits for rural communities of economic activities based on natural resources.

Introduction

Until recently, policy makers often assumed that forests had no economic value unless they were logged as few studies had valued NTFPs (Swanson and Barbier 1992, Godoy et al. 1993). The important role of NTFPs in Amazonia was highlighted in a seminal paper by Peters et *al.* . (1989). They suggested the long term financial returns from harvesting NTFPs in one hectare of rainforest outweighed the net benefits of either timber production or agricultural conversion of the same area of land. More recently, numerous studies have examined local use of forest resources in a wide range of geographic, ecological and socio-economic settings. For example, using participatory valuation techniques, a study in Kenya indicates that forest adjacent communities make use of a wide range of forest products. These contribute substantially to subsistence practices, particularly for domestic consumption i.e. within the household (Emerton 1995b). Other studies support the view that trade in NTFPs is economically attractive. Based on market surveys in Burkina Faso, Guinko and Pasgo (1992) demonstrated substantial marketing of edible NTFPs, predominantly by women. The economic return from trade in forest products was much higher than the local minimum daily wage, although individual income varied by product, season and the number of sellers. In another study, Gunatilake et al. (1993) used a farming systems approach to examine the role of NTFPs in a rural economy in Sri Lanka. They showed a high village dependency on forest resources, with 63 per cent of total income and 59 per cent of cash income originating from forest resources.

Martin (1995) notes that much current research attempts to assess the value of non-cultivated resources harvested from forests and farmplots. From a theoretical stance, this allows a comparison of the economic value of different land use options. The total economic value of NTFPs from tropical forests has been studied extensively, particularly in Latin America. The net values vary widely, ranging from US $1 to US $420/ha/year, due to variation in the biological and economic diversity of different study sites (Godoy et al. 1993). Inclusion of indirect economic values, such as the environmental services provided by extractive forests, increases the estimates substantially. One study in deciduous forest in India (Chopra 1993), estimates the total present value of non timber goods and services as at least US $4034/ha, if use, option and existence value are all taken into account.

While numerous studies document the importance of NTFPs to rural people and estimate the total economic value of tropical forests, there are problems in calculating the potential income from marketing NTFPs. Salafsky et al. (1993) identify ecological, socio-economic and political parameters that determine the potential of, and constraints to, NTFP marketing. These need to be considered in the design and implementation of extractive reserves. Ecological factors include the density and seasonal availability of the target species, together with the sustainability of harvesting at the species and habitat level. Socio-economic and political factors include resource tenure, physical and social infra-structure, market demand and the pressures for alternative land use. Hence, although Godoy and Bawa (1993) suggest a median figure of US$ 50/ha as the annual opportunity cost of forests for NTFP extraction, the many parameters that affect the marketing of natural resources question the use of such a figure. A case-wise approach is likely to provide a more realistic estimate of the local value of forest products to local communities.

While the viability of economic trade in NTFPs may be strongly questioned, the rationale for extractive reserves for conservation is also disputed by some authors. Reviewing extractor households in Amazonia, Browder (1992) takes the extreme view that NTFP harvesting is economically, socially and ecologically unattractive. He argues that the principal concern for extractor households is food security, obtained from small-scale farming and livestock production, rather than NTFP extraction. He contrasts the popular image of extractors in harmony with their environment, with a more pragmatic one: local people attempting to minimise risk and capitalise on commercial advantage, regardless of their ecological impact. He cites examples of resource degradation as evidence of the 'tenuous foundation that prevailing extractive systems provide...a model of sustainable forest development based on extraction'. The poverty of extractor households implies that their land use may be governed by exploitative social relations with landowners, traders and merchant intermediaries and should not, therefore, be deemed exempt from environmental impact.

In another study in Amazonia, Pinedo-Vasquez et al. (1992) studied rural subsistence and market-oriented land use based on both extraction of forest products and forest exploitation for swidden agriculture. They note little incentive for forest product extraction activities because returns are lower than those from swidden agriculture. This is attributed to the relatively high availability of land, insecure resource tenure and uncertain markets for NTFPs. Similarly, Bishop and Scoones (1994) compared the economics of NTFPs used in basket making in rural Namibia with agriculture, beer brewing and drought relief. They demonstrate that the average returns to labour in basket making are significantly lower than returns to any other activities.

This chapter examines the opportunities and constraints for the marketing of NTFPs harvested from LMNP. As outlined previously, many factors affect the marketing value of a product and strategies to improve NTFP marketing may be adapted from those developed for agricultural products. Gittinger (1982) outlines the tangible benefits of agricultural intervention strategies, which arise either from increasing the value of production or from reducing costs. These include: increased production, quality improvement, improving temporal value (change in time of sale) or locational value (change in location of sale), changes in product form, cost reduction through mechanisation and reduced transport costs to access alternative markets.

Because NTFPs are not cultivated, many of these parameters could improve trade only in the long term. Improving the quality or quantity of forest products may be achieved only through selective breeding and cultivation within plantations or forest-crops. The perishable nature of many NTFPs and poor rural transport and communication networks make it hard to enhance temporal value through storage. Most NTFPs are sold in a raw form and the absence of rural industries restricts initiatives to change product form to improve the 'value added'.

Improving locational value through transporting NTFPs from an area where prices are low, and/or markets saturated, to distant markets, where prices are higher and demand unmet, is one method of improving trade that benefits both suppliers and consumers. This is usually a transfer from rural to urban areas. The two parameters, locational value and transport costs, are clearly linked: the ability of isolated, rural communities to access alternative markets efficiently depends on the transport costs. The cost of transport is important in assessing the economic efficiency of markets (Scarborough and Kydd 1992). In a competitive and economically efficient market, differences between prices obtained in spatially separated markets for identical commodities are a function of transport costs, including normal profit. Therefore, interspatial price differences can be compared to the costs of transport to assess economic efficiency.

Using methods adapted from economic analyses of agricultural markets (Scarborough and Kydd 1992), transport costs and interspatial price differences are analysed for NTFPs marketed at Chembe village (rural and local) and Monkey Bay town. Monkey Bay is a market town which is a trading centre for many surrounding villages (see Chapter 2, Figure 1). It is 24km away from Chembe, accessed by a dirt road with no public transport. The data presented are used to assess the efficiency of spatial arbitrage, specifically the degree of integration, or potential integration, of markets separated by distance. They reflect the potential for developing small-scale rural industries based on the sustainable use of natural resources.

Methods

A combination of formal and participatory research methods was employed to assess the potential for marketing NTFPs harvested from the National Park woodlands. Participatory methods included a Strengths/Weaknesses/Opportunities/Threats (SWOT) analysis (FAO 1989), undertaken by villagers to outline local issues in the trade of natural resources. The dynamics of trade were investigated using interviews and participant observation (Pelto and Pelto 1978) of vendors to examine: quantity, price, availability and seasonality of NTFPs.

The price of forest products traded in local and urban markets was recorded during fieldwork undertaken from August 1993 to November 1994. Market surveys (Martin 1995) were undertaken frequently to ensure detection of forest products as they entered the local system. Average prices, with no reference to seasonal fluctuations (which tend to be minor), are presented for a range of NTFPs sold both locally and in Monkey Bay. The sale of mangos was included in this study as many villagers included this fruit when questioned about their trade in 'wild' fruits. Local trading measures (e.g. cups or heaps) were used for pricing, and standardised into baskets to enable comparison between different resources. Except for fuelwood and grass where the unit is a bundle, unit prices are 'per basket', based on the quantity of each item that may be fitted within a standard basket used in trading. The charges for transport, per person and per unit of product, in accessing markets were recorded.

Handling costs include the price of a market stall and an estimate of the opportunity cost of labour for one day, which is the potential earnings foregone by taking produce to market. Four days labour is used for each fish marketing expedition reflecting the longer time required to access a more distant market (see below). Labour costs in developing countries are difficult to calculate because of the under-employment associated with subsistence occupations of a highly seasonal nature (UN/GoM 1993). Martin (1995) suggests that labour should be fixed at the national minimum wage or the typical daily wage that an agricultural labourer earns in the region. However, villagers living adjacent to the national park have few opportunities to access paid labour, in either the formal or informal sector within the region. Hence, labour was priced from local economic activities, rather than national labour rates. This is thought to provide a more realistic estimate of the opportunity cost of local labour.

The opportunity cost of men's and women's labour was calculated separately, according to the employment options available within the village. The economic activities pursued by women in the thirty focal households in each of two villages (Chembe and Msaka) were recorded as part of routine household surveys (Casley and Lury 1987, see Chapters 3 and 6). The surveys showed the importance of primary resources harvested from the Park woodlands for income generation: two thirds of households sell firewood at least occasionally and 15 per cent of households sell grass at least occasionally. Thus fuelwood collection appears to be the most frequent income generating activity undertaken by women and this was used to estimate the opportunity cost of their labour (see Appendix 8). For men, the major economic activity in the villages is fishing and the opportunity costs of their labour was calculated from a recent study of the artisanal fishery and the returns to labour on fishing trips (see Smith 1993a and Appendix 8).

The opportunity cost of women's labour is used in analyses of the profit margins for NTFPs as prior research demonstrated that women, rather than men, are the typical collectors of forest products for income generation (see Chapter 4). The opportunity cost of men's labour is used for estimating the price margin for fish as this activity is undertaken predominantly by men.

Analysis

The urban price margin (M) was calculated according to the following equation (adapted from Scarborough and Kydd 1992):

$$\mathbf{M = (P_m - T_{cm}) - (P_c - H_c)}$$

where:

P_m	Unit price, Monkey Bay
P_c	Unit price, Chembe
T_{cm}	Transport and handling costs in accessing Monkey Bay market
H_c	Handling costs in accessing Chembe market.

The price margin is a measure of the degree of integration of markets separated by distance. If markets are economically efficient the price difference between two markets that trade will approximately equal transport costs. Between two markets that do not trade, the price difference will be less than transport costs (Scarborough and Kydd 1992).

Sensitivity analyses were carried out to assess the impact of transport costs and the quantity of produce traded on the urban price margin. The analyses assume that all produce transported is sold and none is damaged or remains unsold. Unless otherwise indicated, all prices are in Malawi Kwacha (MK), with an approximate exchange rate of £1 : MK25.

Results

Table 1. The urban profit margin for marketing selected NTFPs contrasted with the urban profit margin for fish.

Item	Farmgate Unit Price (Chembe)	Urban Unit Price (Monkey Bay)	Transport costs per person and one unit of product[1]	Handling costs[2]	Urban Price Margin
Tamarind fruit *Tamarindus indica*	10	15	12	2.2	- 7.00
Baobab fruit *Adansonia digitata*	6	9	12	2.2	- 9.00
Masawo fruit *Ziziphus spp.*	20	5	15	2.2	- 30.00
Mango fruit *Mangifera indica*	8	12	14	2.2	- 10.00
Firewood	5	10	13	2.2	- 8.00
Grass	3	4.50	13	2.2	- 11.50
Grasshoppers	50	50	12	2.2	- 12.00
Flying Termites	100	140	12	2.2	28.00
Fish [3]	1100	1690	253.60	18.10	336.40

[1] Transport Costs:
MK 10 return per person and MK 2 - 5 per unit, depending on weight of product. For grass and firewood the unit is one bundle. A unit is one basket for all fruit and insects. One basket contains: 500 Tamarindus indica fruit, 60 Adansonia digitata fruit, 1000 Ziziphus spp. fruit, 80 Mango, 500 Grasshoppers and 200 plates of flying termites.

[2] Handling Costs:
Market stall fee MK 0.50 per day and opportunity cost of women's labour for one day @ MK 1.70 per day (see Appendix 8). For fish, the cost of two days labour and a market stall for two days are included, market stall fee in Blantyre is MK 1.20 per day.

[3] Fish is marketed in Blantyre, the commercial centre of Malawi, rather than Monkey Bay. Urban profit margin is calculated per trip, rather than per unit, see the Discussion for a fuller explanation.

Table 2. Local perspectives on trade based on NTFPs.

STRENGTHS:
Wide range of NTFPs harvested by local villages
Resources are renewable (but depends on harvesting pressure)
A few NTFPs are currently sold or traded
WEAKNESSES:
NTFPs tend to have low economic value
Limited local market for NTFPs
Low quantity of some key, tradable NTFPs locally
Transport to alternative markets inconsistent and expensive
Private rather than public transport
Urban price margin is low
Capital required to start business and meet initial transport and handling costs (see Appendix 9)
Transport costs are often high because many NTFPs are bulky and heavy
OPPORTUNITIES:
New road to Cape Maclear offers opportunities for improved, and possibly public, transport to Chembe and Msaka villages
Enhancement planting to increase availability of key species
Promotion of private initiative for cultivation of NTFPs in village
THREATS:
Sustainability of NTFP use given large population and limited resource base

Discussion

Trade in NTFPs

Table 1 outlines the potential urban price margin for marketing NTFPs at distant markets. The analysis illustrates that spatial arbitrage is profitable for just one NTFP, flying termites. For this resource, the price margin exceeds transport costs and allows normal profit to be made by rural producers. Insects play an important role in the diets of peoples in tropical and sub-tropical regions, providing an abundant source of protein (see Ramos-Elorduy 1993). Flying termites (Order Isoptera, *Macrotermes falciger*) are highly favoured and economically valuable in Malawi (Berry and Petty 1992). They are found in termitaria which are characteristic of *miombo* woodland (Malaisse 1978).

The results suggest the urban price margin for other resources (tamarind, baobab, mango, firewood and grass) is insufficient for rural people to benefit by transporting products to Monkey Bay i.e. the urban price margin is less than the transport and handling costs. Urban trade is also not viable for NTFPs, such as grasshoppers, for which the interspatial price difference is zero. Trade may be profitable in the reverse direction for resources, such as masawo, where the urban price is lower than the local price. Indeed, I met one man transporting masawo from Monkey Bay to sell in Chembe where the price is higher than in the urban market. Masawo has a low economic value in Monkey Bay town because it is common in the surrounding areas, although less common at Chembe.

Marketing of NTFPs indicates that the price of a product is related to its availability. As anticipated from basic 'supply and demand' economic theory, higher prices are attached to products for which there is a supply constraint. NTFPs, such as flying termites and masawo, occupy 'niche markets' where product demand exceeds availability. Thus, it may be predicted that profitable spatial arbitrage is unlikely for NTFPs that have an extensive distribution or for which there is no supply constraint.

This research supports this hypothesis because resources, such as firewood and grass, that are distributed throughout the Park, show low spatial arbitrage. Similarly, profit margins are low for widely cultivated fruits, such as mangos, or those, such as baobab, which are common on the lakeshore plain (Shorter 1989).

In her study of Zambian *miombo*, Hinchcliffe (1993) documented the economic importance of insects, especially caterpillars. Her findings suggest that caterpillars provide a substantial, seasonal income for people in *miombo* areas. Their value was attributed to their demand in areas outside of the *miombo* areas where they occur. This is analogous to the flying termites in this study which are in demand outside of LMNP where they are found. Hinchcliffe suggests developing the controlled sale of caterpillars as a method of enabling communities to benefit from conservation. She notes that insects may provide an alternative when large mammals, which underpin successful wildlife utilisation schemes such as CAMPFIRE (see IIED 1994), are absent. This is the case in her study site of Kasankha Game Reserve, Zambia and also in Lake Malawi National Park. However, the unpredictable inter-annual variation in insect populations may make such initiatives problematic.

The present analysis was undertaken using the opportunity cost of women's labour as they are the prime traders of natural resources. The opportunity cost of men's labour is nearly five times higher than that for women (see Appendix 8), reflecting the different employment opportunities open to both groups. Clearly, the marketing of NTFPs would be even more unprofitable if the cost of men's labour was included, although the sale of flying termites would remain a viable activity. Men's employment prospects in fishing, despite the decline of this industry through over-fishing (Smith 1993a), are significantly better than the women's alternative, trading in fuelwood and other forest products. This suggests that men are unlikely to trade in NTFPs, supporting my observations and the assertions of informants (see Chapter 4, Table 2), that the sale of natural resources is undertaken primarily by women.

It appears that the two markets of Chembe and Monkey Bay are not well integrated and show a low potential profitable spatial arbitrage. PRA discussions, in particular the SWOT analysis of marketing NTFPs (Table 2), highlighted the problems of rural-urban trade and helped discern local trading issues. Both the data presented and village discussions suggest that a principal marketing constraint is the low economic value of most NTFPs compared with the high cost of local transport. The latter is attributed to the poor communications and absence of public transport in this rural area. Padoch (1992) proposes that constraints such as sparsely settled rural populations, poorly developed transport and communication networks and highly uncertain markets at regional, national and international levels, make trade in NTFPs a high risk venture.

Urban marketing of NTFPs could become a profitable venture if a commodity from the town were brought back to the village to be sold as the reverse direction trade would offset the travel costs. However, the present analysis is under the current economic conditions in Chembe: there is a limited sector of the population with sufficient wealth to purchase commodities brought from the town. Fishermen have the greatest involvement in a cash economy but they have access to the towns to purchase products independently when they trade their fish. Thus, there appears to be little potential for a flow of goods from the town to the village. Furthermore, a capital outlay would be required to engage in reverse direction trade to make the urban marketing of NTFPs profitable. This is beyond the means of most people (see below).

Urban profit margin is a measure of the potential for markets to be connected. It shows where profitable trade is possible but does not show: whether price incentives are responded to, how high profits have to be to ensure trade, whether the means to respond is available (transport considerations) and whether producers have information about alternative markets (Scarborough and Kydd 1992). The poor communication associated with rural areas, and protected areas in particular, suggests that many of these limitations apply. Recent research in human ecology suggests that indigenous knowledge networks are incomplete and people act on imperfect or limited information (see Stephens 1990). Thus, while alternative markets may exist for NTFPs, it is quite plausible that rural people do not know about them. Furthermore, even if the information is available, local transport is both expensive and unreliable, restricting the ability of local people to capitalise on potential spatial arbitrage.

Sensitivity Analysis: transport costs

A sensitivity analysis was undertaken to establish the effects of the cost of transport on urban profit margin. Transport costs may change due to a number of external factors. They may be reduced if public transport becomes available at Chembe. This may be feasible since the completion (December 1994) of an improved road from Chembe to Monkey Bay. Conversely, recent devaluations in the local currency have increased the price of fuel, forcing transport costs to rise. Unfortunately, the price of local goods has not increased in the same proportion as transport costs, which has the effect of reducing potential profit margins. Another option is for a vendor to walk to Monkey Bay and reduce their transport costs to zero, given that the opportunity cost of one day's labour in accessing markets is already included in the price margin equation. However, the 2-3 hour walk through the Park woodlands to access Monkey Bay would not be possible for heavy resources, including certain fruits (mangos or masawo) and firewood.

The results of the sensitivity analysis are shown in Figures 1 - 5. They indicate that transport costs would need to decline by at least 80 per cent for trade at Monkey Bay in any of the fruits (mango, tamarind or baobab), firewood or grass to break even (Figures 1 - 3). Should resources be carried to Monkey Bay on foot, transport costs are zero and a small profit could be made. This is feasible only for light NTFPs, such as baobab, tamarind or grass. Regardless of transport costs, urban trade will not be economically viable for NTFPs with no interspatial price difference (grasshoppers) or those with an urban price lower than the local price (masawo). The urban profit margin of marketing flying termites increases with decreasing transport costs. Figure 4 demonstrates that transport costs could increase by more than 80 per cent and spatial arbitrage still remain profitable for this product.

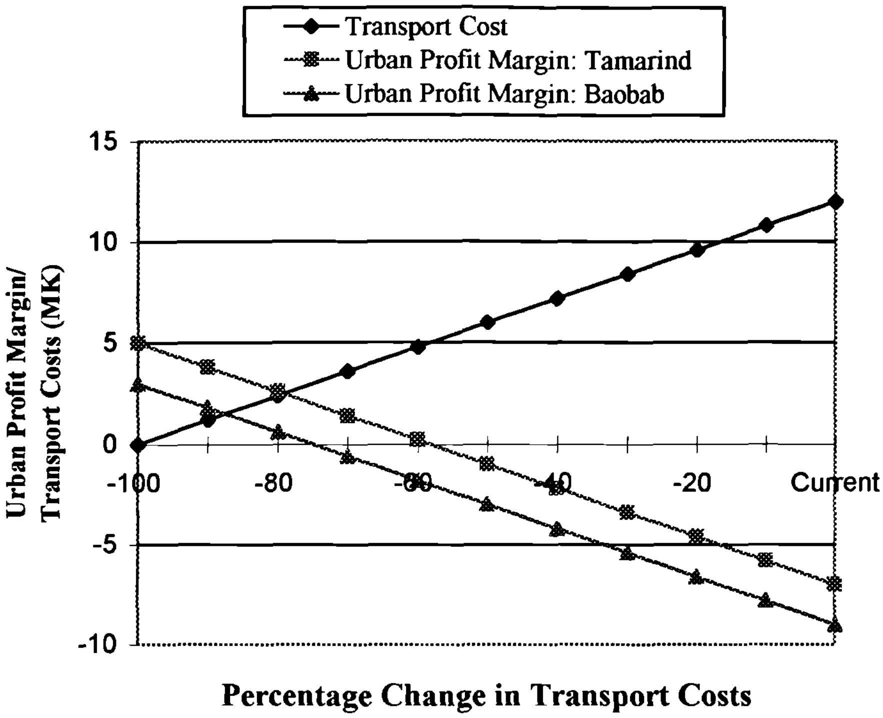


Figure 1. Sensitivity analysis of the urban profit margin to transport costs for two fruits, tamarind and baobab.

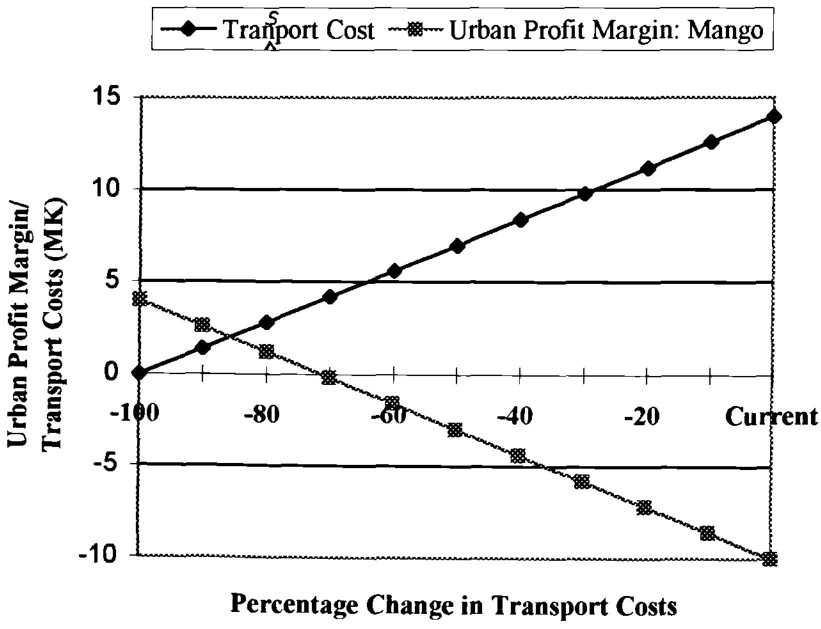


Figure 2. Sensitivity analysis of the urban profit margin to transport costs for mango fruit.

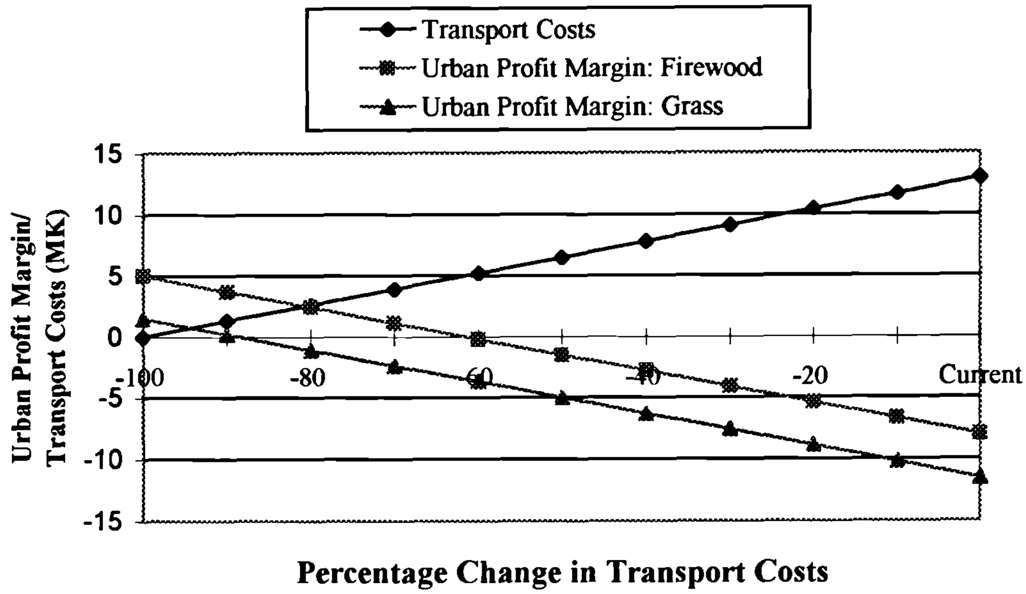


Figure 3. Sensitivity analysis of the urban profit margin to transport costs for grass and fuelwood bundles.

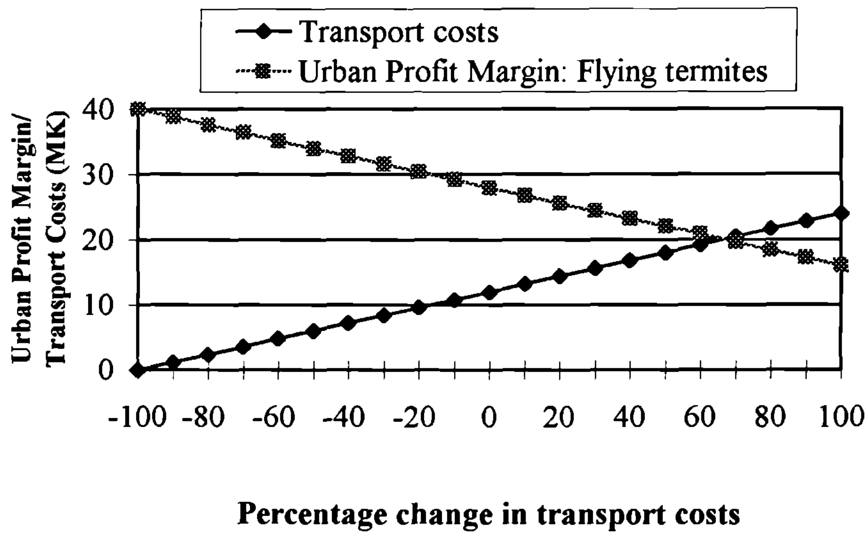


Figure 4. Sensitivity analysis of the urban profit margin to transport costs for an insect, flying termites.

To compare the viability of different economic activities, the profit margin for marketing fish, the major economic activity in Chembe (Smith 1993a) is included. Traders buy fish in Chembe and sell in the urban city of Blantyre. The high profit margin of this activity is demonstrated in Table 1. Figure 5 shows that a viable fish trade is also possible even with increases in transport costs of more than 10 per cent.

However, it is likely that any increase in fuel prices would be reflected in a corresponding increase in fish prices because fish has a national demand, yet limited distributive supply. A robust trade in fish is therefore assured. This contrasts with products, such as masawo fruit, which are distributed more widely and therefore have local demand only.

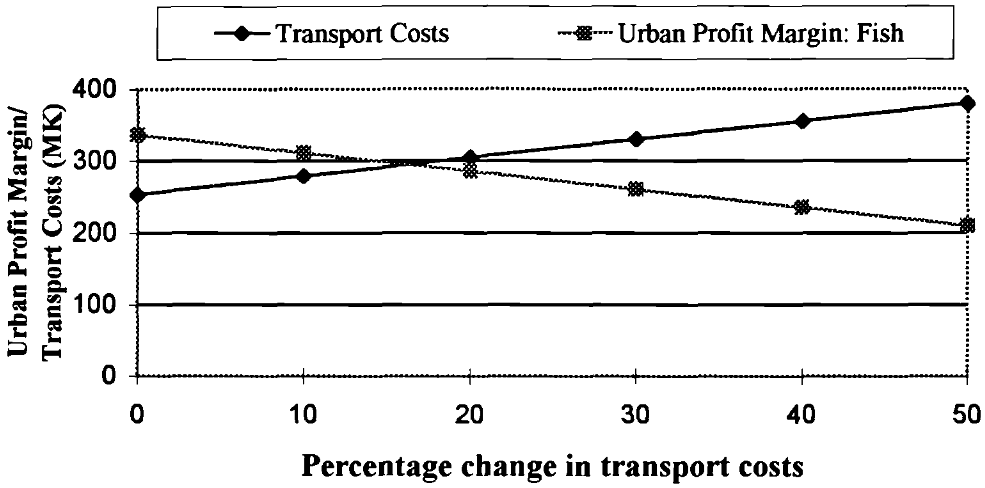


Figure 5. Sensitivity analysis of the urban profit margin to transport costs for fish marketing in Blantyre.

The relationship between fuelwood and fish trading is an interesting one. Table 1 suggests that as a raw product it unprofitable to trade fuelwood outside of Chembe village. However, fuelwood is used to process fish for sale in inland towns, which is a highly profitable venture (see Table 1). Thus, fish smoking is a process that adds value to fuelwood, a pre-requisite for preserving fish and transporting it to rural markets. As outlined in Chapter 6, fuelwood used in fish smoking is collected by men, either by the fishsmokers themselves or male woodsellers (see Chapter 4, Figure 4). For women, the only profitable trade in fuelwood is the local market, relying mainly on sales to more affluent households in Chembe or the tourist industry. Because transport costs are not incurred in the local sale of fuelwood, this activity is profitable despite the lower price for fuelwood locally compared with urban centres.

Given the urban profit margin for fish sales would be higher for women than men (because of their lower opportunity costs of labour), it may be questioned why the major economic activity for women is selling fuelwood rather than fish. While some women buy fresh fish and process it for sale to fish traders, few women market fish in urban centres where the high potential profit is to be made. This may be due to the high capital costs associated with fish trading (Table 1), to which few women would have access. Furthermore, trading activities are unlikely to fit in with the demands of childcare activities (see Chapter 8) and it is also inappropriate for women in this society to travel unaccompanied to urban areas.

The opportunity cost of capital in Chembe is high (600 per cent *per annum*, see Appendix 9) because there are few money lenders in the village. The high capital demands associated with fish trading restricts this activity to richer sectors of the village and particularly to men, who control financial resources. By contrast, marketing NTFPs is available to poorer sectors of the community because, withstanding lower profit margins, lower levels of capital investment are required. Indeed, the wealth ranking outlined in Chapter 4 reveals that local, village trade in fuelwood and grass is undertaken predominantly by women from the poorest households in the village (see Appendix 1). Trade in such NTFPs is expedient for poorer households because no costs are incurred except in terms of the time and energy expended in collection (see Chapter 9). Furthermore, by selling directly to richer households in the village or to the tourist support industries, women reduce their handling costs and do not incur a market stall fee. A similar finding is outlined by Bishop and Scoones (1994) in a study of NTFP use in Namibia. They suggest that basket making is important for women because it requires little capital investment and can be performed in conjunction with other more seasonal activities, such as agriculture.

Table 1 suggests that fish trade is much more profitable than marketing NTFPs. It should be noted, however, that the fish-trade data are obtained from direct observation and interviews with fish traders in Chembe and reveal real marketing strategies and associated profit. This contrasts with the NTFP scenario, which is hypothetical, reflecting potential profit margins gained by changing the location of sale from rural to urban settings. Two differences are important in this context and affect the apparently high urban profit margin exhibited by fish traders: the location of sale and the number of units traded.

Firstly, fish from Chembe is traded in Malawi's commercial centre Blantyre and not traded in Monkey Bay. Monkey Bay was used in the NTFP marketing analyses because it is the most accessible urban centre for villagers. However, discussion with fish traders from Chembe reveals they do not trade their fish in Monkey Bay because, as a port, it has its own fishing industry. Consequently, the interspatial price margin would be insufficient to accommodate trade from Chembe fish traders. By marketing fish from Chembe in inland towns, such as Blantyre, Dedza and the capital Lilongwe (see Chapter 1, Figure 1 and Chapter 4, Figure 4), fish traders obtain maximum spatial arbitrage, although the high transport costs should be noted. It is possible that spatial arbitrage could be improved for other products characteristic of the lake shore, such as baobab fruits, by changing the location of sale to inland towns. However, urban price margins would have to be high to offset the high costs of transporting NTFPs of low economic value.

Secondly, the urban profit margin for fish is based on observations of profitability per trip, rather than per unit, which was the measure used to standardise profit margins across the NTFPs. Based on what was actually transported, it appears that the urban profit margin for fish is contingent on trading large quantities, often in excess 300kg. From interviewing fish traders, it is clear that there is a minimum amount of fish that must be transported to secure sufficient profit on each trip. Because the urban profit margin for fish depends on the quantity of fish transported, a sensitivity analysis was undertaken to investigate whether the urban profit margin of NTFPs could be improved by increasing the number of units sold.

Sensitivity Analysis: quantity transported

This sensitivity analysis was undertaken with no reference to the availability of NTFPs or the sustainability of harvesting. For many NTFPs a supply constraint may affect the amount which may be traded. However, the point of this analysis was not to determine the feasibility of harvesting large amounts of NTFPs, rather, to investigate whether marketing strategies for fruits and fuelwood and grass could be improved by trading a greater number of units.

Transport costs consist of two components: fixed invariable costs and variable costs. Fixed invariable costs are those incurred in transporting the vendor to the point of sale. The costs imposed in transporting the product to the point of sale are variable costs, because the total cost depends on the number of units transported. Because a greater cost is incurred in transporting the vendor rather than the product to the point of sale, relative transport costs may be lowered by transporting a larger number of units. Thus, it is hypothesised that the incremental costs of transporting additional units of product may offset the fixed invariable cost of transporting the vendor, and potentially improve the urban profit margin by trading greater quantities.

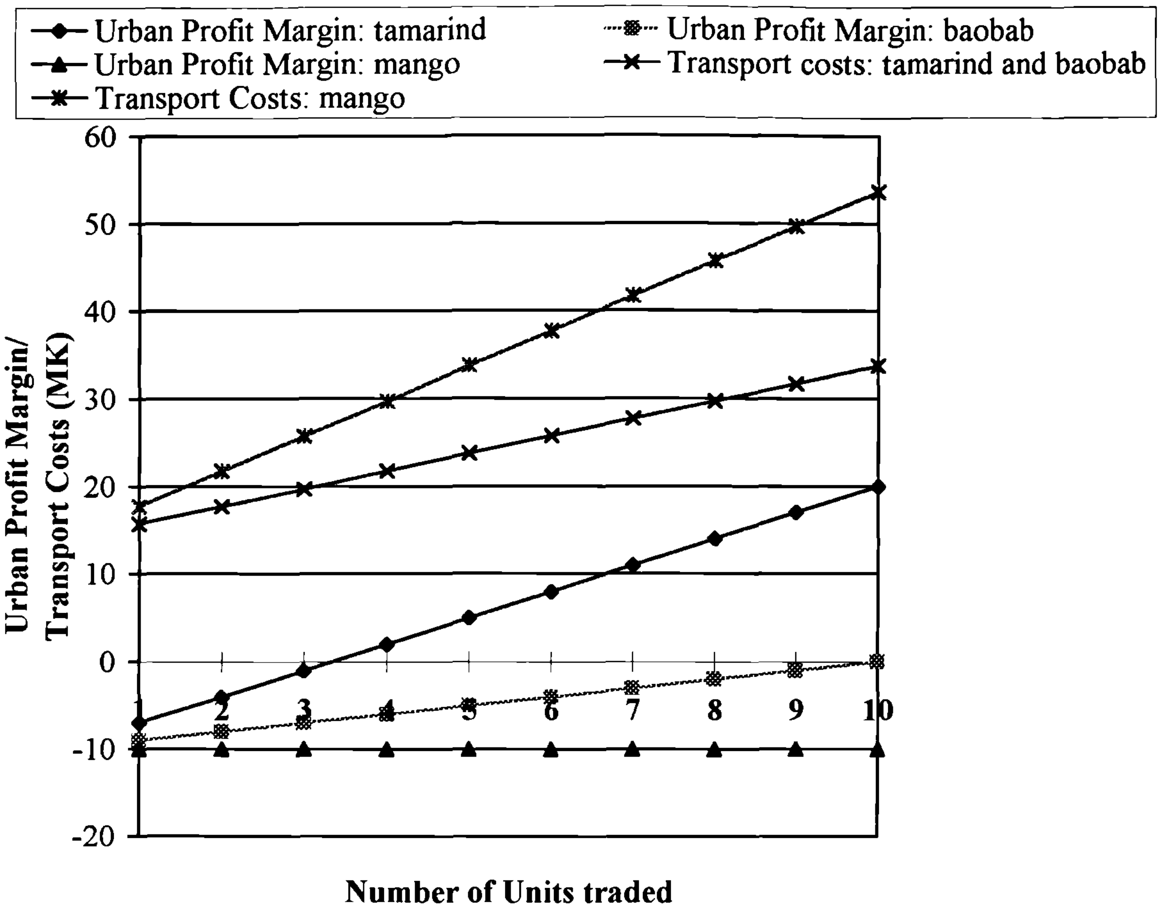


Figure 6. Sensitivity analysis of the urban profit margin to the number of units traded for three fruits: tamarind, baobab and mango.

The results of the sensitivity analysis (Figures 6 and 7) suggest the total transport costs are too high to offset the increasing profit gained by marketing additional units of products. The urban profit margin for the three fruits, grass and fuelwood is insufficient to offset travel costs even for trade in large quantities of products. By contrast to fish, the economic value most of the NTFPs is insufficient to warrant their transportation to distant markets. Clearly, for flying termites, the urban profit margin increases with an increase in the number of units traded. However, there is a supply constraint with this product: the availability of flying termites is limited spatially and temporally, being found in termitaria within the woodland during the rainy season (Berry and Petty 1992, CCAM 1992).

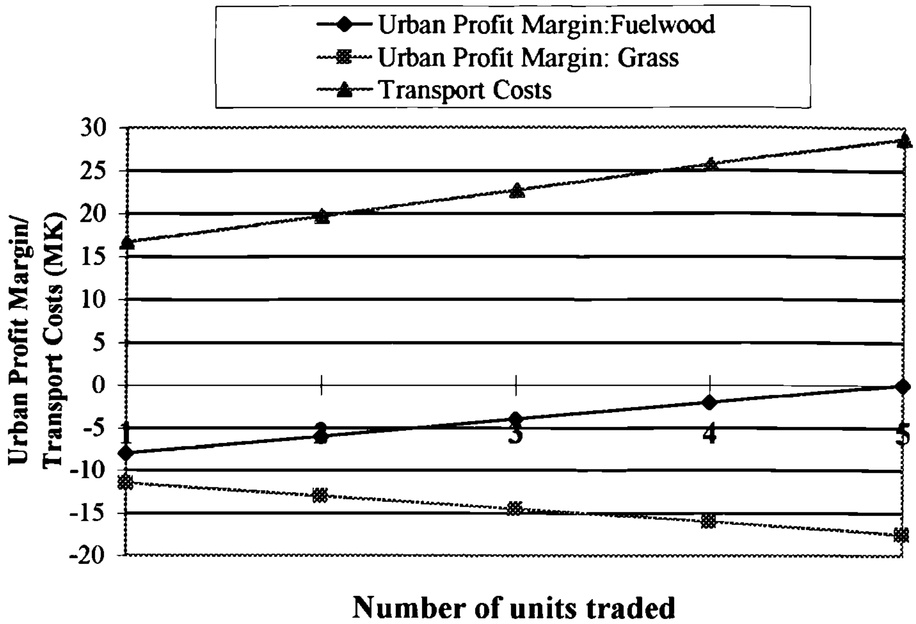


Figure 7. Sensitivity analysis of the urban profit margin to the number of units traded for fuelwood and grass bundles.

Other studies also suggest that NTFP harvesting is constrained by the ecology of the target species. From a study of the population dynamics of trees bearing NTFPs in Malaysia, LaFrankie (1994) demonstrates that projected incomes are too small to be profitable and are negligible compared to the extraction of multi-species crops of timber. He suggests combining multiple NTFPs within a 'High Diversity Forestry' scheme, improving the economic viability of trade through increasing the density of harvestable species and reducing the associated costs of labour. Peters (1992) suggests that NTFP extraction is easier and economically more profitable in oligarchic forests than species-rich forests. The advantage of forests dominated only by a few species is that yields of NTFPs approach those of commercial plantations and management to increase production is unnecessary.

Conclusions

The present study has identified three basic constraints to the urban marketing of NTFPs from LMNP. These relate to the availability of the product, the low economic value of most NTFPs and the high cost of transportation to alternative markets. While NTFPs, such as insects and wild fruits, are sold in Monkey Bay market, it is not profitable for people from Chembe to trade their products there. It appears that trade in low value NTFPs is feasible only for people with better access to the market town e.g. the Park villages of Chidzale and Zambo, as well as many other smaller villages on Nankumba Peninsula (see Chapter 2, Figure 1). A similar marketing problem has been identified for rural communities living around Korup National Park, Cameroon: poor communication impedes trade in relatively heavy but low value forest products and food crops (Amadi 1993, see Chapter 1).

Thus, isolation appears to be a constraint to improving the marketing of natural resources by rural communities residing in or adjacent to protected areas (see also Medley 1993). At Chembe, there is no public transport and villagers rely on private transport (local pick-up trucks) to access Monkey Bay. The high cost of this transport, compared with the low retail price of NTFPs, appears to preclude exploitation of the urban market. Local sale of products is profitable although opportunities for trade are more limited because of the small population of the village. Moreover, traders within Chembe must compete to sell similar products to a limited number of consumers.

Medley (1993) suggests the commercial value of many NTFPs is low because of the absence of marketing strategies for many natural resources. Hinchcliffe (1993) noted the key role of intermediaries in her study of caterpillar trade in Zambia. Merchant intermediaries ('middlemen') from the Copperbelt Region establish exchange points for villagers, reducing local transport costs and enabling traders to barter collected larvae for consumer goods. Such developed marketing strategies may help to enhance the efficiency of trade, although the question of sustainable resource use underpins conservation strategies based on NTFP marketing. Hall and Bawa (1993) distinguish between ecological and economic sustainability, noting that the terms are neither synonymous nor, necessarily, compatible. Over-harvesting may lead to a decline in populations while persistent demand keeps the market value of the product constant. Unfortunately, increasing economic returns may be associated with harvesting an uncommon resource. Thus, while the potential for trade in flying termites was demonstrated in this study, the availability of sufficient quantities of termites for viable and ecologically sustainable trade remains a moot point.

Because the urban price margin for most NTFPs is insufficient to offset the cost of transport, local markets are a better option for trade, despite the lower prices received. This is particularly the case for resources, such as firewood and grass, with high transport costs and/or a wide distribution. By contrast, the urban fish trade is highly profitable (although, as outlined previously, the urban profit margin for fish should not be compared directly with that for NTFPs). Fish is a highly valued resource because it is a major source of protein in Malawi (Walter 1988). There is national demand for a product with a supply constraint, restricted to lakeshore and riverine areas. Flying termites, also a source of protein, were identified as a NTFP with a similar marketing pattern to fish i.e. a resource with limited availability, restricted to termitaria within *miombo*, but high demand at a regional level. Notwithstanding the supply constraint to this insect, the potential for profitable economic trade in flying termites was demonstrated in this research.

Thus, the market for the product appears to be an important factor affecting trade. Viable trade seems plausible only for specialised products for which there is high demand for a local product. Commercial trade is unlikely in the absence of products of regional, national or international significance. Yet reviewing historical trade in gum arabic in West Africa, Hanson (1992) suggests that commercial expansion precipitated social and environmental degradation in the gum-producing areas of the region. Similarly, Homma (1992) cautions that trade in NTFPs with commercial demand is subject to changing market requirements. In an historical review of extraction in

Amazonia, he examines the dynamics and economics of trade in NTFPs, such as cacao, rubber and Brazil nut. He presents three developmental stages to resource extraction: expansion, stagnation and decline. He attributes decline in NTFP harvesting to the following factors: inelastic forest supply of NTFPs, harvesting rates in excess of regeneration, domestication of the product and the development of industrial substitutes. Thus, he argues that while NTFP harvesting is an important economic activity in the short term, it does not provide a satisfactory forest development model. Furthermore, May (1991) recognises the risk for rural people in becoming over-specialised, and vulnerable to market shifts by focusing on a few products, or on commodities obtained through newly developed trade channels. Rapid growth in market demand can also degrade forest resources if local communities are unable to maintain control over the rate and intensity of extraction and are marginalised by commercial extractors.

The present study supports recent research highlighting significant obstacles faced by extractive reserves designed with the dual role of conserving natural resources and providing viable economic activities based on these resources for local people. Analogous to the findings of Salafsky et al. (1993), the present analysis suggests that while extractive reserves may play a role in conservation, there are major limitations to developing trade in NTFPs. The success of trade in such products depends on 'prevailing local ecological, socio-economic and political conditions' (Salafsky et al. 1993). These work in combination with national and international economic and political factors to influence the marketing of NTFPs and define the ultimate success or failure of an extractive reserve. May (1991) outlines the importance of appropriate institutional mechanisms, covering all phases of NTFP development, production and marketing, for effective rural development contingent on NTFP extraction. At LMNP, viable economic trade is contingent on increasing production of key species, reducing transport costs and widening the point of sale.

The current rationale for the conservation of the *miombo* woodlands of LMNP is to protect watersheds and prevent siltation of the aquatic habitats of the cichlid fish

(LMNP Master Plan 1981). Thus, while urban trade in NTFPs may be unprofitable for most resources, the environmental services provided by *miombo* woodlands may provide a better justification for their conservation than an extractive reserve. Furthermore, at the household level, NTFPs make a significant contribution to rural domestic subsistence (see Chapters 4 and 6), even if trade, both urban and rural, is more limited.

As the fishing industry declines (Smith 1993), the tourist industry generated by LMNP may provide an alternative source of income that appears, based on preliminary calculations (see Abbot 1995), more profitable than trade in NTFPs. As LMNP tourism expands (Jalale 1993), it plays an increasingly important role within the Chembe economy. Thus, tourism, rather than the urban marketing of NTFPs, may provide viable economic options for households and supplement the declining fishing industry. Furthermore, the turnover in tourists provides a continuous (albeit seasonal) market for NTFPs such as fruits, particularly mango. Although the urban marketing of NTFPs appears unprofitable on the basis of these analyses, the more limited local trade in NTFPs is likely to remain an important economic activity for poorer households in the village.

Chapter 8

Families and fuelwood: the role and effects of children in the collection and use of fuelwood.

Summary

The household has been a convenient unit of study for this thesis although earlier chapters outlined the heterogeneity of the household and the different roles individuals play in resource collection and use. In particular, Chapters 4 and 6 outlined gender and age differences in patterns of collection and use of natural resources. This chapter explores in more detail the collection of domestic fuelwood and its use within the household. As outlined in Chapter 1, fuelwood is an important woodland product, enhancing household food security and nutritional status (Brouwer et al. 1989). Fuelwood collection in LMNP is an arduous task undertaken exclusively by women accompanied by their daughters. The present study examines patterns of domestic fuelwood collection and the effects of children on the household time budget. It discusses household collection and use of fuelwood in terms of household size and the value of children in subsistence economies. An improved understanding of patterns of use of fuelwood and the actors in wood collection in LMNP provides an informed basis for establishing participatory woodland management strategies.

Introduction

Patterns of Fuelwood Collection and Use within Lake Malawi National Park

Firewood is the main fuel used among the villages of LMNP, although maize stalks are used, as available, during the harvest season. Fuelwood is used for domestic purposes (i.e. cooking and heating water) on open fires, usually three-stone hearths. As outlined in Chapter 4, natural resources show specific collection patterns with regard to gender and age. These tend to reflect the traditional division of labour. Typically, cooking and other domestic activities are undertaken by women. As a prerequisite for cooking and a household requirement, fuelwood collection is undertaken by women. Older daughters may assist women in fuelwood collection activities. My observations, and those of an earlier study of subsistence patterns in the 1930s-1940s (Berry and Petty 1992), suggest that from the age of ten years, daughters assist their mothers collecting fuelwood. Boys were never observed collecting firewood.

Fuelwood Collection and Use: background and approaches

Most studies on female subsistence and childcare activities focus on female agricultural labour (Levine 1988, Panter-Brick 1989) or gathering of wild food items (Kaplan 1994, Hurtado et al. 1985 & 1992, Blurton Jones et al. 1989). This chapter explores the collection and use of domestic fuelwood, a subsistence and foraging activity undertaken predominantly by women. By examining one subsistence activity the research generated detailed time allocation data on fuelwood collection. As outlined previously, fuelwood is an important resource making the major components of the diet, maize and fish, suitable for human consumption. Domestic fuelwood collection is female-labour intensive and one of the most arduous household maintenance tasks (e.g. Cain 1977). Labour is a direct measure of investment in the household economy and a study of fuelwood collection therefore provide an analysis of female investment in a principal element of household subsistence.

Despite the plethora of studies undertaken since the 'fuelwood crisis' was highlighted in the 1970s (see reviews in Agarwal 1986, Leach and Mearns 1988, Mundslow 1988 and by Soussan et al. 1992 and Murray and Montalembert 1992), very few studies have measured fuelwood consumption directly or related its use to household size. For example, an extensive Rural Energy Survey in Malawi interviewed 2408 households but failed to include any questions regarding quantities of fuelwood consumed (Energy Survey Unit 1984). When calculated, the methodologies behind many fuelwood consumption rates are difficult to ascertain. A report from the Malawi National Energy Plan (OPC 1988) notes that many studies assume an average *per capita* consumption of 680 kg *per annum* for rural dwellers yet although widely cited, they found no explanation of how this figure was calculated nor any empirical basis for that assumption. Where methodologies are explicit, they tend to rely on questioning women regarding the number of bundles they use over a specified period and weighing a sample of bundles (e.g. Bell 1978). However, such methods are open to problems of accuracy associated with any study based on recall (see Marr 1971). Other studies measure fuelwood brought into a household or village over a specified period (e.g. Hartley 1992). However, without measuring fuelwood stockpiles and the remainder of wood at the end of the study period, this methodology says more about patterns of fuelwood collection than consumption.

Most studies quote *per capita* fuelwood consumption. It seems intuitive that this will vary with household size through economies of scale yet few studies have addressed this issue. An exception is an early study detailing fuelwood use from a Tanzanian village by Fleuret and Fleuret (1978). While based on recall estimates of consumption and a small sample size (four households), the study questioned women from households with three and five residents. They showed that *per capita* fuelwood consumption decreases with increasing family size, the larger household using just over 1 kg more than the smaller household.

Child Participation in Household Labour

Many studies highlight the burden of rural subsistence tasks on women, in terms of the time allocated to household maintenance tasks and the energetic costs of load carrying (e.g. Kandyoti 1987, Ellis 1988). Fuelwood collection, in particular, appears to be one of the most energetically demanding household tasks for women (e.g. Mehretu and Mutambirwa 1992). Less well studied is the role of children in household subsistence activities, such as fuelwood collection. Brouwer et al. (1989) suggest that in areas suffering fuelwood shortage, there may be a shift in labour division within households, with greater participation by children or even men. Fleuret and Fleuret (1978) note that '[f]emale children begin to help their mothers almost as soon as they can walk, and it is not unusual to see five- or six- year-old girls....with bundles of twigs on their heads'. Because schooling is increasingly available in rural areas, Mehretu and Mutambirwa (1992) observe that the burden of household maintenance tasks rests on women as female children, who traditionally assist with these tasks, are unavailable on school days. But in areas with decreasing fuelwood availability, children may be kept home from school to assist with wood collection (Eckholm et al. 1984).

Aside from these general observations, the level of participation by children in fuelwood collection is not well documented. Thus, the section that follows presents a more general review of the expanding literature on the desire for, and role of, children in subsistence economies.

The Role of Children in Household Economies and Theories of Fertility

There is much debate on the value of children and its relation to fertility levels and trends in developing countries. Children may be valuable to parents in two main ways: by participating in current household labour and by providing future economic support for their ageing parents. It is as a source of household labour that children will be discussed in this chapter. Cain (1983) considers that too much research values child labour rather than studying the role children play as an 'insurance against risk' in parents' old age. While it is true that much recent research documents the value of children to the household economy, the results often conflict (see below). Thus, it remains unclear whether children are a net cost or benefit to their parents and equivocal whether child labour is the driving force behind the high fertility levels found in developing countries. Furthermore, as noted by Turke (1989), many studies use interviews to estimate child labour force participation (e.g. De Tray 1983). Because children tend to work less intensively than adults, recall techniques are likely to overestimate child work effort because 'work time' will include elements of play or other distractions (Betzig and Turke 1985). Hence, methods of direct observation, such as time allocation, are preferable for more accurate assessments of child labour.

In an early study, Nag, White and Peet (1978) outlined an economic interpretation of fertility. They cited econometric analyses that demonstrate significant positive correlations between measures of child labour-force participation and birth rates in some developing countries. In their study in Java and Nepal, they measured the direct, economic costs and benefits of children to their parents at a household level, concluding that children contributed 'quite substantial' labour to the household. They suggested that in the villages studied, 'children probably have a net positive economic value to their parents', besides the old-age security they may also provide. Other, more recent studies also document high levels of child labour in different populations.

Studies of food acquisition by Bird et al. (1993) and Hawkes et al. (1993) indicate that children are productive both through self provisioning and contributing to the household food budget.

The direction of inter-generational wealth flows are central to Caldwell's (1983) theory of fertility and demographic transition. He suggests that high fertility levels are economically rational for households in developing countries because the net wealth transfer from children to parents is positive. Caldwell views the fertility transition as a social transformation of the family including: reduction in family networks with emphasis on nuclear rather than extended families, erosion of traditional lines of authority and a reversal of wealth flows such that children (through their reduced labour and increased schooling etc.) become net costs to their parents. In this post-demographic transition regime, the net wealth transfer from children to parents becomes negative, parents desire fewer children and limit their fertility.

Criticism for Caldwell's wealth flows theory of fertility is both empirical and theoretical. Cain (1982) acknowledges that Caldwell has helped displace the common assumption that high fertility is never economically rational in the developing world but disagrees that child labour represents an argument for limitless high fertility. Based on his study of economic activities in Bangladesh (Cain 1977), he argues that the product of children's labour does not compensate for the cost of their cumulative consumption (mainly because girls are much less economically productive than boys and the rigid gender division of labour precludes female participation in most economic activities outside of the household. Female labour in domestic tasks and food production are not valued in economic terms, see below).

While these data conflict with the findings of Nag, White and Peet (1978) and the predictions of a wealth flows theory of fertility, they are entirely compatible with fertility theories derived from evolutionary biology (see Turke 1989, Kaplan 1994). These suggest that natural selection favours organisms that are able to transfer resources extracted from the environment into genetic material carried in their offspring. Hence, in contrast to Caldwell, evolutionary theory predicts that wealth flows from adults to children should always be positive, or as expressed by Kaplan (1994), the acquisition of wealth should be in the service of reproduction rather than *vice versa*.

Kaplan tested empirically the opposing predictions of the directions of inter-generational wealth flows generated by Caldwell's and evolutionary theories of fertility using data from three traditional, pre-demographic transition societies in South America. Using measurements of age-specific food production and estimated consumption, he showed that in these high-fertility populations, children were costly to raise. Up to age eighteen years children contributed less than one quarter of what they consumed (although this may be an under-estimate because Kaplan failed to measure child self-provisioning with food items). Thus, both Cain's (1977) study of economic activities and the more recent and extensive foraging study by Kaplan (1994) lend little support to a wealth flows theory of fertility which predicts that children should make a positive contribution to the household economy.

Reconciling Childcare and Subsistence Activities

Furthermore, children may have a negative impact on the ability of their parents, particularly their mothers, to work efficiently. Among South American hunter-gatherer communities, Hurtado et al. (1992) note the trade-off between the time and energy women allocate to child care and to foraging activities. They note that while both these activities are potentially fitness-enhancing, they are, to some extent, mutually exclusive. In their study of female food acquisition and child care activities among Hiwi and Ache foragers, they found that nursing mothers spend less time foraging and acquire less food than non-nursing women. While children may impair the ability of their parents to forage efficiently (cf. Blurton Jones 'backloading models', see below), this finding is also consistent with evolutionary theory. This predicts that nursing women, as the primary caretakers of children, should undertake activities that enable them to concentrate more effort into the successful development of their children.

It is especially difficult for women to combine child care activities with agricultural work or other labour, such as trading or foraging, that require prolonged periods away from the household. The methods by which women accommodate infant and child care within heavy work schedules are poorly understood. Levine (1988) notes that there are limited options for nursing women who undertake foraging or agricultural work. These include: neglecting work and minding the children (often not an option for poor households or those heavily dependent on female labour for subsistence activities), working, albeit less efficiently, accompanied by infants and children, or where available, leaving the children with caretakers in the village. Various factors influence the decision-making between the pursuit of subsistence *versus* child care activities. These include: the physical constraints imposed by carrying or supervising children (e.g. Blurton Jones 1978), the level of danger in the environment (the number of 'health insults', Hurtado et al. 1992 and perceived or 'mystical' dangers, Levine 1988) and the availability of alternative childcare (e.g. Turke 1988). Siblings and post-reproductive women are frequent caretakers of young children. They can enhance a nursing woman's ability to forage or work away from home for prolonged periods, provided they supply adequate child and infant care.

Objectives

This chapter examines the relationship between fuelwood consumption and household size. Fuelwood consumption is measured directly rather than using recall methods. This allows a comparison of the energy efficiency of different sized families. These data are used to construct longitudinal models of household fuelwood consumption. Furthermore, using time allocation studies, the effects of children on fuelwood collection are investigated in two ways. Firstly, the fuelwood collection patterns of nursing and non-nursing women are compared. Secondly, the foraging activities of daughters who assist their mothers in fuelwood collection are examined. This enables an analysis of whether children are a net cost or benefit to their parents in terms of the fuelwood they consume *versus* the fuelwood they contribute to the household.

Specific Objectives

- to examine whether infants constrain women's foraging efficiency, by contrasting the fuelwood collection activities of nursing and non-nursing women
- to examine how efficiency of fuelwood use varies with household size, and use this relationship as a basis to build longitudinal models of household fuelwood consumption
- to examine the direction of inter-generational resource flows through modelling children's net fuelwood consumption
- to relate patterns of fuelwood collection and use to theories of fertility and determinants of family size.

Methods

Household Fuelwood Survey

Fuelwood surveys were undertaken in two of the villages, Chembe and Msaka, monitoring the flow of fuelwood through each of the sixty target households over the same period of seven consecutive days each month. The methods of household selection and detailed schedules for the fuelwood survey have been described previously in Chapter 6. The data generated from these surveys are explored more fully in this chapter.

Time allocation studies of wood collection activities

Focal group sampling (Altmann 1974, Gross 1984) was employed to derive time budgets for wood collection for women from Chembe village. Time records were maintained for the entire period that the focal group was collecting fuelwood, i.e. from the time they left the village until they returned. Focal studies that employ such continuous recording techniques are considered to be well suited to the study of differences in work patterns because a sequence of activities can be recorded (Borgerhoff Mulder and Caro 1985).

Focal group follows were undertaken approximately once per week and on any day, Monday to Saturday (no fuelwood collection is undertaken on Sundays). On wood tracking days, the researchers walked through the village (either early in the morning or afternoon, depending on the schedule of other research and surveys) and selected the first group of fuelwood gatherers encountered. Because of the large size of the village, the researchers entered the village using different paths to ensure that women from all sectors of the village (i.e. households on the periphery as well as those in the centre of the village) were tracked.

This method, while not strictly random, ensured that we only followed women who were undertaking their routine fuelwood collection trips. A truly random method, i.e. selecting a focal household using a random numbers table and visiting each day to check when the woman would undertake a trip, was logistically difficult to schedule around other research. More importantly, it might affect her fuelwood collection (in terms of destination or load) by compelling her to undertake a trip when not necessarily required. Thus, the method selected was a compromise, ensuring a range of women were tracked according to their usual patterns of fuelwood collection. The women seemed not to mind the researchers accompanying them and did not appear to modify their wood collecting behaviour. In fact, the European carrying a bundle of wood, albeit a small one, on her head seemed to add to everyone's enjoyment of an otherwise arduous task!

By accompanying women on wood collection trips, the time spent walking *versus* gathering and the weight of wood collected were recorded. In addition, each woman was asked when she last collected wood to derive estimates of the frequency of wood collection trips. Women were weighed with, and without, their fuelwood bundles using stand-on digital Salter weighing scales. Bundle weight was calculated by subtracting the woman's weight from the combined weight of the woman with the bundle loaded on her head. The researchers recorded the presence of any daughters who were accompanying their mothers and weighed their bundles separately. Similarly, nursing mothers, collecting fuelwood with babies tied to their backs, were noted. In total, forty-two groups of women from Chembe were tracked on fuelwood collection trips during the study. Additional analyses of these data are undertaken in the next chapter which explores the decision making in woman's foraging behaviour.

Appraisal of methods

The household fuelwood surveys measure fuelwood consumption directly and provide detailed information on energy efficiency and household size. These surveys, combined with the female time budgets for wood collection, allow the role of women and their children in one subsistence activity to be assessed. Whilst I would like to contrast wood collection activities by gestating and lactating women with non-nursing women, data are categorised as nursing (i.e. lactating) and non-nursing women only. Local taboos preclude inquiry into pregnancy and women do not admit being pregnant until they give birth. Because it is difficult to identify gestating women, especially in the early stages, I do not have data on their foraging activities. However, my observations suggest that women continue routine subsistence work late in their pregnancies.

Reproductive histories for all the tracked women would have enabled more tests of various theories of fertility to be undertaken. However, it was not feasible to obtain precise demographic data *and* detail fuelwood collection activities. Thus, demographic data from the thirty, randomly selected households participating in the fuelwood surveys in Chembe are used as representative of the community as a whole. It is thought that by using conservative estimates from these data, together with published surveys from similar communities in Malawi (Berry and Petty 1992, UN/GoM 1993) and census data from Chembe (Grenfell 1993), that realistic models of fuelwood collection, use and the effects of children on female labour can be built.

Results

The results are displayed in Figures 1 to 8 and Table 1. Statistical analyses were undertaken using the programme, Statistical Package for the Social Sciences (SPSS Version 6.1). Statistical tests are considered significant when the probability ≤ 0.05. For some comparisons, for example of nursing and non-nursing women, non-parametric methods of statistical analysis were used. These are recommended for analysis of results with a small sample size and unequal sized samples (Kinnear and Gray 1995, Norusis 1995). Parametric methods of data analysis were used when the sample sizes were larger and showed an approximately normal distribution (i.e. index of Skewness < 1.0) (Sokal and Rohlf 1995). *Post hoc* or unplanned multiple comparisons were made using Tukey's Honestly Significant Difference (HSD) test (Norusis 1995).

Figures 1 and 2 contrast the wood collection patterns of nursing and non-nursing women. Nursing women are defined as those undertaking a fuelwood collection trip accompanied by a baby who is tied to her back. Non-nursing women are those women observed collecting fuelwood without babies. Because reproductive histories were not collected for each woman on focal group follows, it is possible that 'non-nursing' women may have infants or babies who remained at the household and such women may, therefore, be lactating. However, this should not affect these results, which seeks to test whether the presence of a baby, rather than the lactating condition, affects the ability of women to forage for fuelwood. The results suggest that nursing and non-nursing women have similar patterns of wood collection, both in terms of the distance travelled and the load collected.

Figure 3 compares the patch residence time of nursing and non-nursing women. Patch residence times is defined as the time spent searching for fuelwood, resting and tying bundles prior to headloading the wood back to the village. The results suggest that there is no significant difference in the patch residence times of wood collection groups that contain at least one nursing mother and those that contain no nursing mothers.

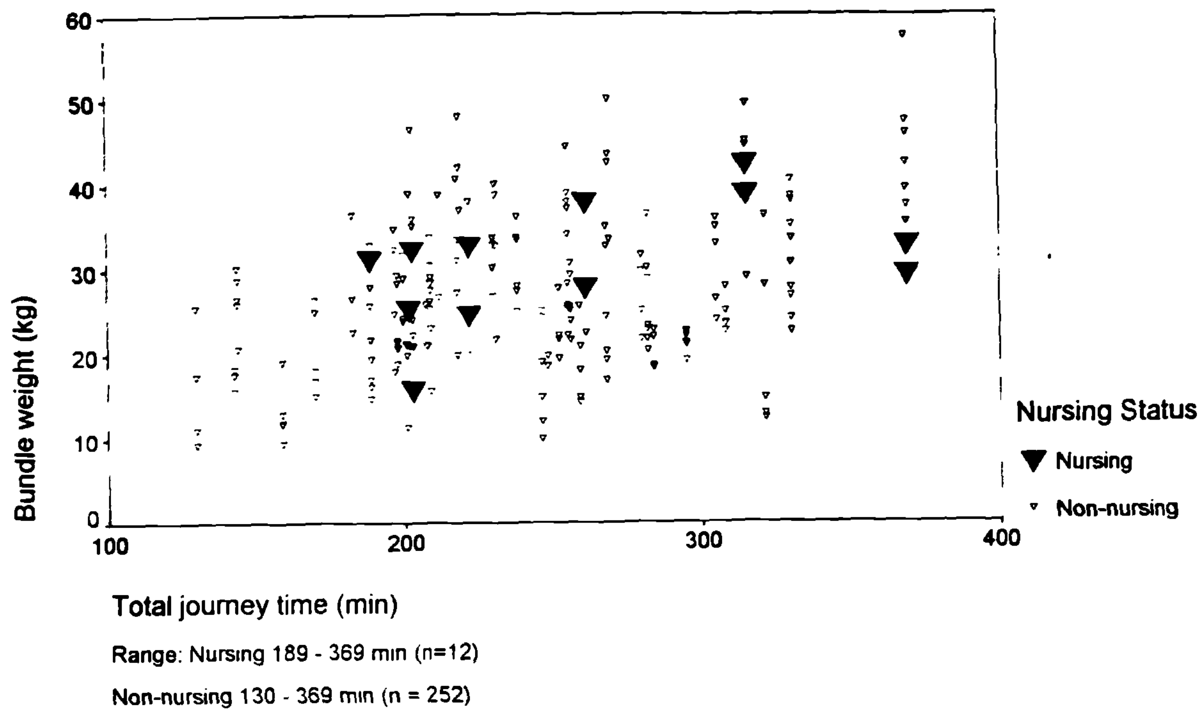


Figure 1. Fuelwood collection by nursing and non-nursing women.

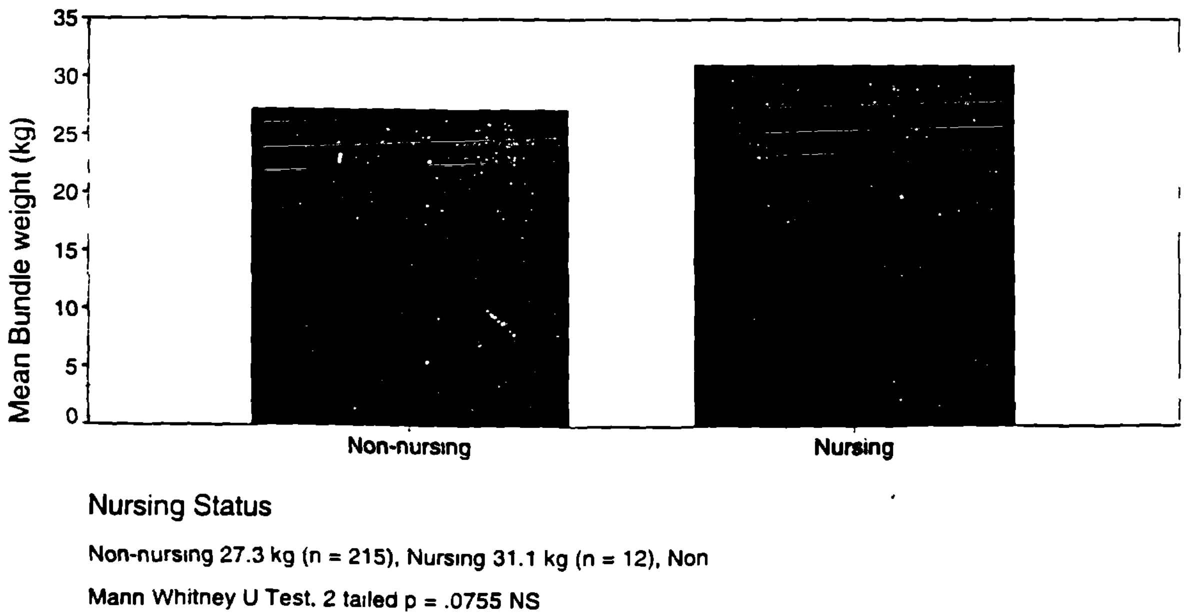
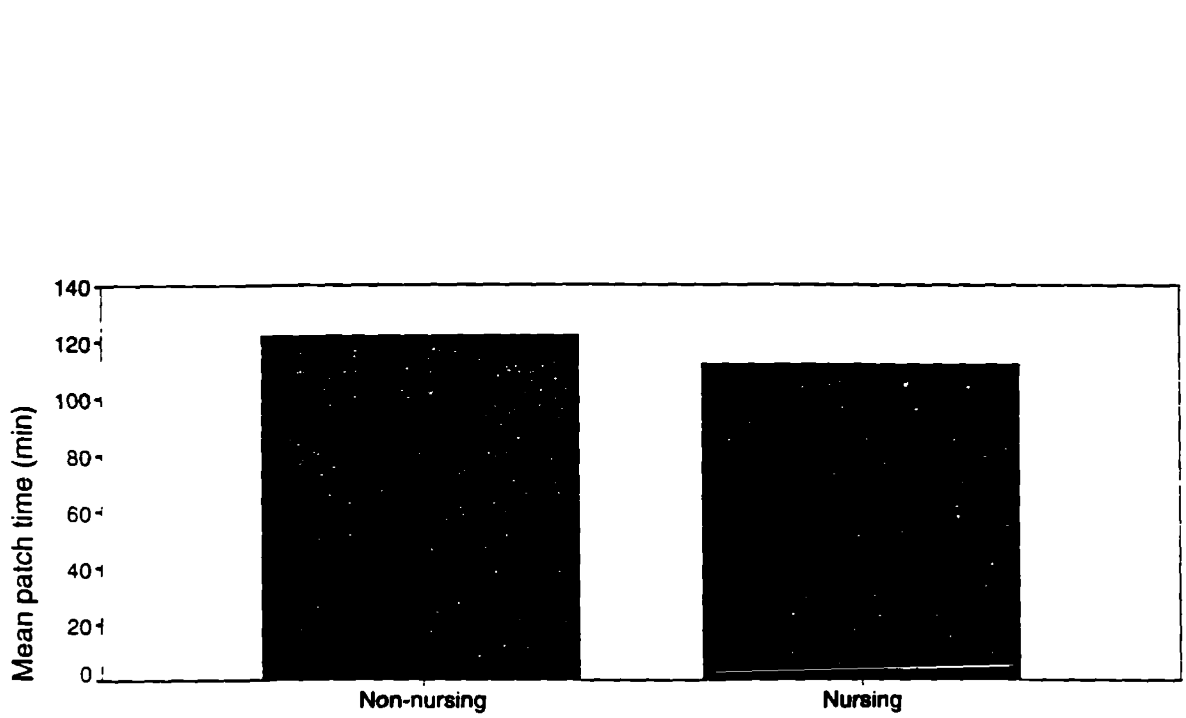


Figure 2. Fuelwood bundles carried by nursing and non-nursing women.



Nursing Status

Non-nursing 125 min (n = 38), Nursing 109 min (n = 7)

Mann Whitney U Test, 2 tailed p = .2595 NS

Figure 3. Patch residence times for fuelwood collection groups containing nursing and non-nursing women.

(Nursing groups contain at least one nursing woman).

Figure 4 plots *per capita* weekly fuelwood consumption with varying household size. Because of the hot and equable climate on the southern shores of Lake Malawi firewood is not used for space heating and there is little seasonality of use (see Chapters 4 and 6). Fuelwood consumption can therefore be expressed as mean weekly consumption averaged across the months of the study. Furthermore, rates of fuelwood consumption reflect the minimum energetic requirements for direct household maintenance: cooking meals and heating water for either purification or bathing purposes. They tend therefore to be lower than other published consumption rates (cf. OPC 1988, Shackleton 1993), derived in colder or more seasonal climates where space heating is required.

Figure 4 indicates the strong effect of household size on energy efficiency. The graph suggests that household size is a good predictor of *per capita* fuelwood consumption. This was confirmed using least squares regression which indicated that 64 per cent of the variance in *per capita* weekly consumption is explained by one variable, the number of individuals resident in the household. A multiple regression of the number of adults and the number of resident children did not improve the prediction of *per capita* wood consumption (R = .45216, F = 23.52, p < 0.01). Hence the regression using just the number of resident individuals will be used in modelling household fuelwood consumption (see below). An inverse curvilinear model is used to describe the relationship between *per capita* fuelwood consumption and household size, generating the following equation:

$$\mathbf{y} = (39.0 \times (1/\mathbf{x})) + 2.98$$

where **y** is an estimate of *per capita* fuelwood consumption and **x** is the number of individuals resident in the household.

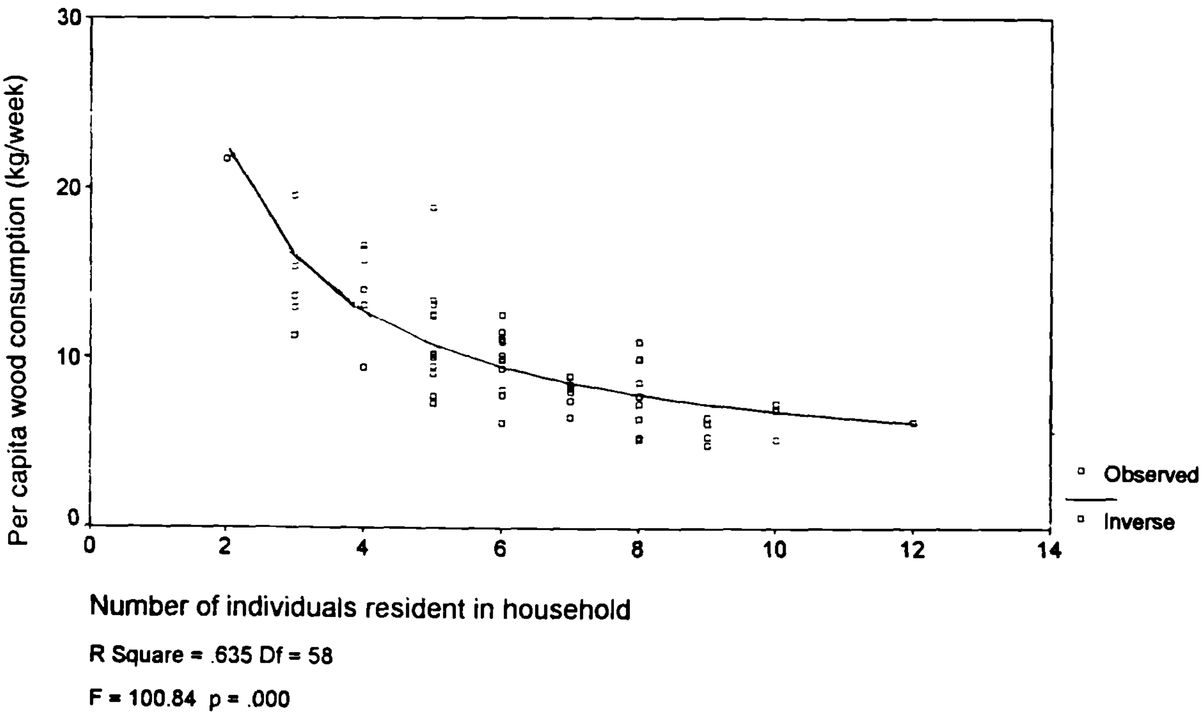


Figure 4. Household size and fuelwood efficiency.

Figures 5 and 6 distinguish the fuelwood collection activities of women who are assisted and unassisted by their daughters. The frequency with which daughters assist their mothers was analysed using records of accompanied women who were tracked on two or more occasions. On average, women are assisted on just over half of their fuelwood collection trips (Table 1).

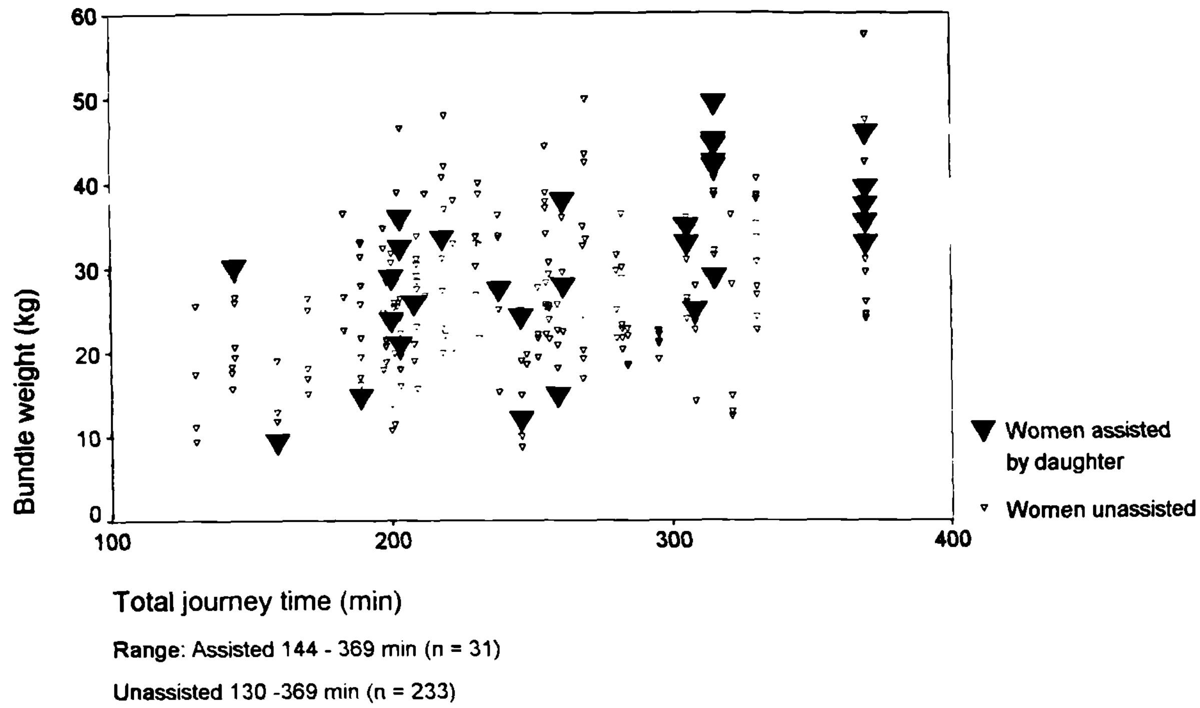


Figure 5. Wood collection by women assisted and unassisted by their daughters.

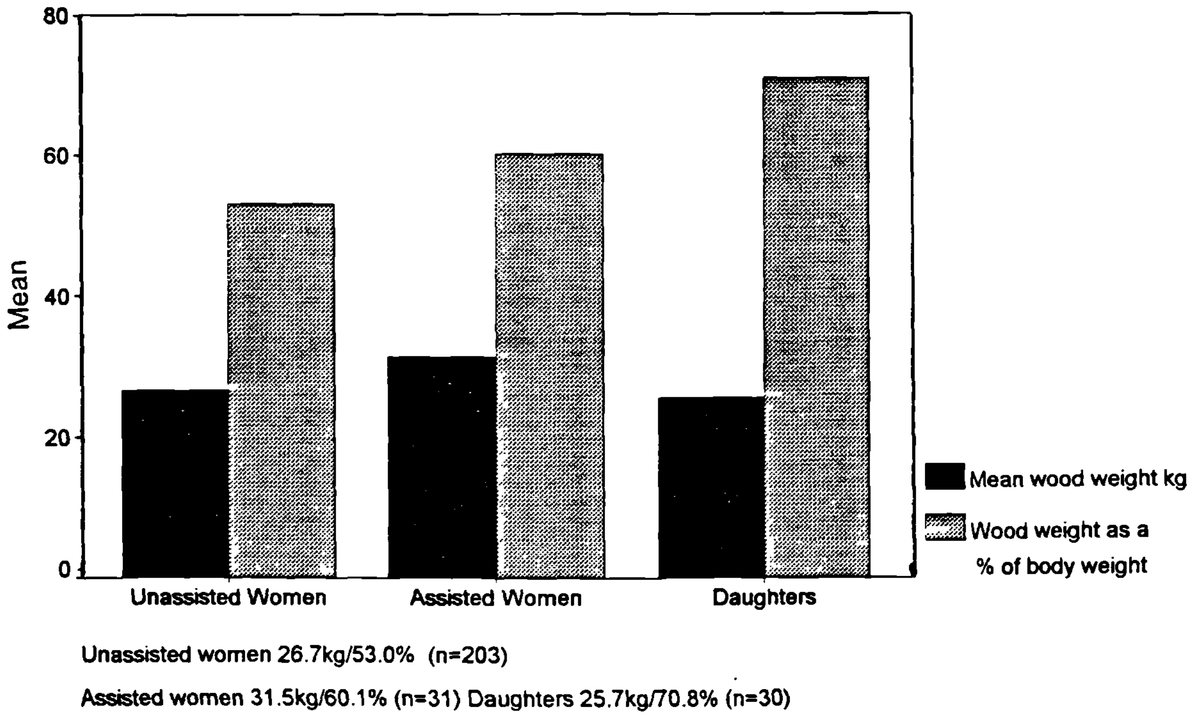


Figure 6. Wood collection by women and their daughters.

Table 1. Frequency with which daughters assist their mothers in fuelwood collection.

Focal Woman	Number of trips on which woman tracked	Number of trips on which accompanied by daughter	Percentage of trips on which woman accompanied
1 Lodiya	4	2	50%
2 Mercy	3	2	67% [1]
3 Lojines	6	3	50% [2]
4 Nabanda	2	1	50%
5 Nyilongo	2	1	50%
TOTAL	17	9	52.9%

[1] a different daughter was present on each of the two trips on which Mercy was tracked
[2] demographic records for this woman show that she has two daughters of appropriate age (10 & 14 years) but only the elder daughter was observed assisting her mother.

The two records of women with two daughters suggest that these women do not receive twice the level of assistance as women with only one daughter. One woman was assisted on only half of her trips, while the other was assisted on two of the three trips for which she was observed. These observations indicate a fairly low frequency of assistance from daughters, albeit based on a sample of five women. Even this could over-estimate a daughters participation in fuelwood collection. Because I do not have demographic data on all the women tracked, it is possible that some women collecting firewood unaccompanied had daughters of appropriate age at home. Futhermore, because I do not have demographic data for the women in Table 1 (with the exception of Lojines), the women may have had other daughters of appropriate age who do not assist them.

To assess the validity of this hypothesis, I cross-checked the demographic records from thirty households in Chembe with any observations of their wood collection behaviours. In total, six women for whom I had reproductive histories were tracked wood collecting. Five of these women collected wood unassisted on the occasion(s) when they were observed. Four of these women either had no daughters or none of an appropriate age. The fifth woman had one daughter of an appropriate age (age fifteen years) but was unassisted on the one occasion she was tracked. The sixth woman, Lojines, had two daughters (aged ten and fourteen years) and was accompanied on three of the six trips on which she was tracked (albeit by the older child only, see Table 1). These findings are considered further in the Discussion section.

Using these data on fuelwood collection and use, a model was constructed to analyse a households fuelwood demand over the lifetime of a family (see Figures 7 and 8). Estimates of household size are derived from demographic data collected from thirty households in Chembe. The mean household size is six people (2.2 adults, range 1 to 4 and 4.3 children, range 1 to 8) and the mean inter-birth interval of surviving children is 3.1 years. For simplicity, the model household has two adults and produces a total of four children, at three year intervals. The 1992 census (Grenfell 1993) indicates an equal sex ratio (50.7% male, 49.3% female in the under 15 year old population), suggesting that the average family would produce two children of each sex. Data from rural surveys in the Southern Region of Malawi (UN/GoM 1993) estimate female marriage at 17 years. Children of both sexes are assumed to leave the household to form their own families at this age. It therefore takes twenty-seven years to establish a household, bear four children and for them to leave to form their own households.

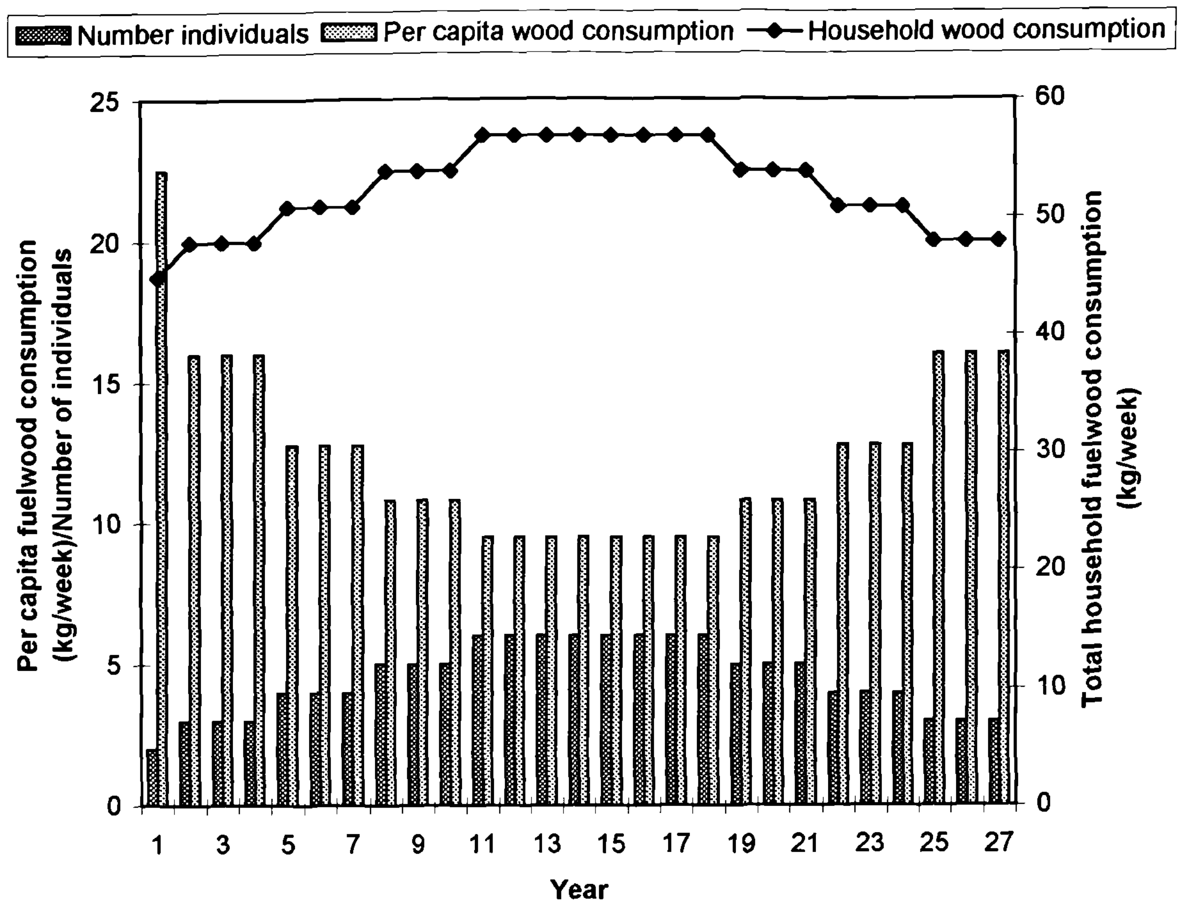


Figure 7. Profile of household fuelwood consumption.

Given that daughters begin to collect fuelwood from about the age of ten years (cf. Berry and Petty 1992), they are able to assist their mothers for seven years. The first daughter is assumed to assist in half of all collection trips that her mother undertakes. Using the observed mean interval between women's wood collection trips of 3.8 days, the first daughter would undertake forty-eight trips per year. Assistance from a second daughter is assumed to be lower: I examine here the consequences of a younger daughter not participating in fuelwood collection and also that she assists in just one third of wood collection trips, i.e. thirty-two trips per year.

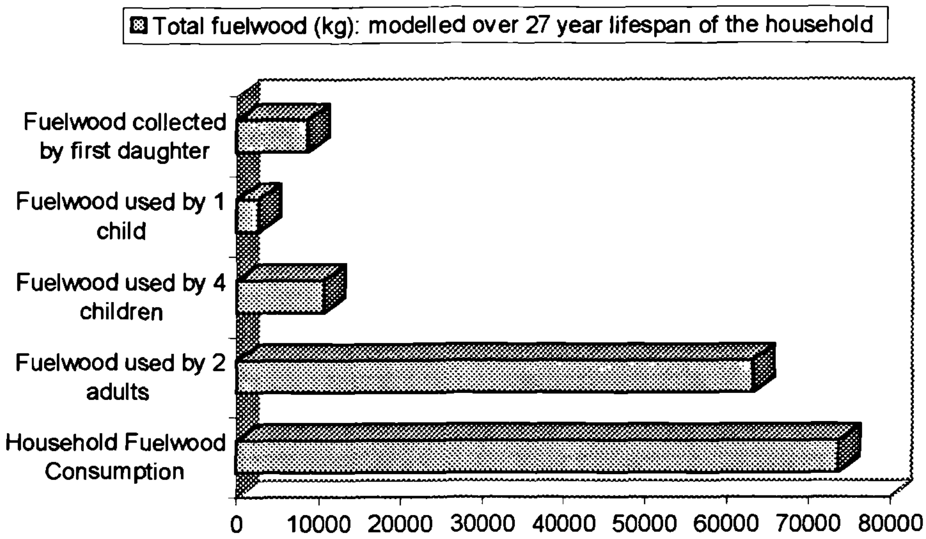


Figure 8. Fuelwood collected by a daughter compared with that consumed within the household.

(Fuelwood used by two adults is the minimum required to maintain the household, the fuelwood used by children is in addition to that consumed by two adults).

Discussion

Fuelwood collection among nursing and non-nursing women

The results suggest that nursing women appear to be equally efficient at fuelwood collection as non-nursing women. Figure 1 distinguishes the wood collection activities of nursing and non-nursing women in terms of the lengths of journeys undertaken. While both nursing and non-nursing women make wood collection trips of varying length, nursing women are neither constrained nor choosing to make short journeys.

Figure 2 shows the mean bundle size carried by nursing and non-nursing women. Contrary to expectations, nursing women appear to carry slightly larger bundles than non-nursing women, although the difference is not significant. This is despite carrying a mean additional load of 7.74 kg: the mean body weight of non-nursing women is 50.54 kg ($n = 215$) while the combined mean weight of nursing mothers and their babies is 58.28 kg ($n = 12$). The significant difference in body weight between the two groups (Mann Whitney U Test, 2 tailed $p = .0015$) is attributed to the weight of the baby tied to the mother's back. However, this may overestimate the child's weight because a nursing mother, who had adequate nutrition during pregnancy, may be heavier than non-nursing women through carrying postnatal fat reserves (FAO/WHO/UNU 1985).

The loads carried by these nursing (and non-nursing) women are substantially larger than the load sizes reported for nursing hunter gatherers by Blurton-Jones et al. (1989). The !Kung carry 'heavy loads' (15 - 20 kg) over long distances, in excess of 9.7 kilometres. The Hadza carry lighter loads (mean 13.6 kg) over shorter distances (estimated at 0.8 - 3.2 kilometres). By contrast, these fuelwood collectors carry heavier loads for journeys of intermediate length. Mean bundle weight is 31.1 kg and the mean distance covered (estimated from pedometer readings and verified with maps) is 3.4 kilometres (range 0.8 - 7.9 kilometres). Clearly, this makes fuelwood collection an arduous task, especially when the topography of the Park is considered (see Chapters 5 and 9). Women have to climb a steep gradient to reach the woodland and return loaded downhill.

The heavy loads carried by African women have been the subject of much recent debate since a paper by Maloiy et al. (1986) suggested that African women can carry headloads of up to 20 percent of their body weight at no extra energetic cost (see also Mitchell 1986, Taylor 1986, Jones et al. 1987, Charteris et al. 1989). The energy conservation mechanism has been explained by more efficient use of the body as a pendulum during locomotion (Taylor 1996, Heglund et al. 1986). These experiments help to explain the large loads carried by African women. It should be noted, however, that all the measurements have been made on a treadmill i.e. for women walking on a flat surface. It is uncertain, though unlikely (Strickland, London School of Hygiene and Tropical Medicine pers. comm.), whether the 'energy-saving gait' can be achieved when walking downhill with a head supported load. Given fuelwood loads are carried downhill at LMNP, the women may not benefit from the 'free-ride' until they reach the flat ground of the village.

Given the local constraints to wood collection, it is surprising that nursing women appear to be as efficient foragers of fuelwood as their non-nursing counterparts. Their fuelwood collection trips and load size appear unaffected by the presence of infants. Although babies do not seem to affect fuelwood collection, the additional weight of the carried baby must have an energetic cost. This is in addition to the high energetic cost of lactation, estimated at between 500 and 700 KCal per day (depending on the woman's level of fat stores, her patterns of activity and the age of the nursing child, FAO/WHO/UNU 1985, Mehretuo and Mutambirwa 1992).

Clearly, the energetic demands of a lactating woman undertaking strenuous physical activity, such as fuelwood collection, are very high. It is unclear whether additional food is available to compensate for her energetic expenditure, especially if lactation coincides with periods of seasonal food stress (Chambers et al. 1981). In southern Malawi, this occurs early in the year when food stocks are depleted and the current crop is not yet ready to harvest. Women from the thirty target households showed a weight loss from February to June, coinciding with this period of food insecurity and hard agricultural labour (author's unpublished data). However, the nutritional and health impacts of wood collection (and other physical activities) on both nursing and non-nursing women, in communities already subject to seasonal food-insecurity, were beyond the scope of this study.

That Malawian women seem unconstrained by their babies conflicts with other findings, outlined earlier, suggesting nursing hunter-gatherers are less efficient foragers. However, these results are consistent with those of Panter-Brick (1989) who studied the subsistence activities of the Tamang of rural Nepal. She found that women's workloads were hardly modified during pregnancy and lactation when there was a high demand for labour. She attributed the behavioural similarity between mothers and non-nursing women to the local, ecological constraints to food production that require high levels of female labour for a household to achieve food self-sufficiency. Given that women must continue to work, even during pregnancy and lactation, there are limited coping strategies: either to integrate the baby into the subsistence work or leave the infant with caretakers. The latter option is taken by a high-altitude population in Nepal (Levine 1988). Tibetan and Hindu mothers leave their children locked in the house or with caretakers when they go to their fields because of the arduous nature of the labour itself and the travel on rough terrain.

By contrast to high altitude Nepalese women, the Tamang (Panter-Brick 1989) like various hunter-gatherer groups (see Hurtado et al. 1985, 1992 and Blurton Jones et al. 1989) and these Malawian women, take their babies with them and integrate childcare into their labour. Women's decision-making in this behaviour is likely to be influenced by various factors but primarily by the degree of dependence on female *versus* alternative sources of labour, the age of the child (see below) and availability of childcare.

Amongst Ache hunter gatherers of Paraguay, alternative child care is lacking because post-reproductive women are under-represented due to premature deaths from contact-related diseases (Hurtado et al. 1985, 1992). Hence, nursing mothers take their infants with them when they forage. The dangerous forest environment requires mothers to be extremely vigilant and, consequently, they show lower foraging efficiency than non-nursing women. This is compensated for by male-provisioning. Ache women produce less than two-thirds of their own daily caloric expenditure and depend on men for the remainder, as well as for provisioning their offspring (Hurtado et al. 1985). The significant contribution males make to Ache subsistence, allows nursing women them to focus their attentions to child care.

Hiwi hunter gatherers of Venezuela, resident in a safer and less demanding environment than the Ache, have more options for reconciling childcare and subsistence activities. While nursing Hiwi are also less efficient foragers, this is compensated for by provisioning and assistance from both post-reproductive women and resident males (Hurtado et al. 1992). In these societies, post-reproductive women work long hours and showed food acquisition rates equivalent to, or in certain seasons exceeding, those of non-nursing women. Similarly, men assisted females in foraging during certain seasons and were responsible for about 30 per cent of child care.

Fewer behavioural strategies are open to the !Kung where female foragers provide up to two-thirds of the household diet (Blurton Jones and Sibley 1978, Blurton Jones 1986, 1987). Given the heavy dependence on female foraging effort, a long inter-birth interval of four years is considered optimal for reproductive success because of the constraints on women who frequently carry an infant (for up to the first four years of its life) and food items over long distances. With shorter inter-birth intervals, a mother would have to carry two infants for prolonged periods at the expense of gathered food items and at increased risk of heat stress through carrying heavy loads in the late dry season.

The present study demonstrates a similar dependence on women's labour despite the strenuous nature of fuelwood collection. Because fuelwood collection is seen as part of domestic activities, it is not undertaken by men. Unable to rely on male provisioning of fuelwood, women have little choice but to develop coping strategies (cf. Panter-Brick 1989). My observations during focal group follows show that these nursing women, like the Tamang of Nepal, integrate childcare into the workplace by feeding babies during rest periods (associated with tying fuelwood bundles before returning to the village). However, Figure 3 shows that there is no significant difference in the patch residence times of wood collection groups with and without nursing women. Hence, women seem to be able to integrate child care into normal patterns of fuelwood collection and do not slow the group by remaining longer at the patch. This contrasts with the behaviour of nursing Hiwi (Hurtado et al. 1992), who integrate child care with foraging for roots by remaining longer in the patch when they are accompanied by their children.

Because demographic data on the reproductive status of each foraging woman were not collected it is not possible to ascertain on what proportion of trips women take their babies or up to what age. However, discussion with the women indicates they carry their babies for the first few months only. This is when they need frequent feeding on demand and cannot be left for the prolonged periods necessary for fuelwood collection (mean total length of observed fuelwood trips was 241 minutes, range 130 - 369 minutes). Estimated ages of the infants (derived from ranking children and using their weights, see FAO/WHO/UNU 1985) suggest that they are much less than one year old. By contrast, the infants of hunter-gatherer groups are carried for much longer periods. For example, !Kung and Hadza mothers carry their infants for up to four years and two years respectively (Blurton Jones et al. 1989). These older, and consequently, heavier children may restrict the amount of foraged food the mother can carry. By carrying children only when they are younger, and therefore relatively light, Malawian women seem to be able to carry large loads and have fuelwood collection patterns that are unaffected by the infant.

An alternative for fuelwood gatherers, especially those with older infants and children, is to leave their children with caretakers in the village (cf. Levine 1988). Because of the steep terrain of LMNP and the heavy loads carried, older, post-reproductive women tend not to undertake fuelwood collection. This leaves them available to care for infants within the village while the mothers collect fuelwood. I do not have data on child care during fuelwood collection trips. But demographic data from thirty households in Chembe show that potential child carers are not limiting: more than one-third of households (37 per cent) contain either a maternal or paternal grandmother. These post-reproductive women may contribute to the household through caring for children, especially older infants who are too heavy to accompany a woman and because they are no longer breastfed frequently may be left for extended periods. Older children may also fill the childcare role (see below).

Household Size and Fuelwood Efficiency

Figure 4 examines the effects of household size on fuelwood efficiency. Two people use over 20 kg of wood each per week. However *per capita* fuelwood consumption declines rapidly with increasing household size, such that in a household of six people each person consumes just under 10 kg per week. The observed mean family size of six people in

Chembe (see Results for explanation) appears an efficient unit for fuelwood consumption. Figure 4 suggests that *per capita* fuelwood consumption begins to levels off at less than 10 kg per week in households containing six or more people. Clearly, larger households are more efficient and consume relatively less fuelwood than smaller households.

Various factors account for the economies of scale in fuelwood consumption i.e. while large households use quantitatively more wood than small households, their *per capita* consumption is lower. Fleuret and Fleuret (1978) propose the inefficiency of semi-open wood fires and suggest that it is more efficient to cook large quantities of food than small because the additional quantities are cooked by heat that would otherwise go to waste. They also note that heating a house for five people would take proportionally less wood than heating a house for three people. However, this is not applicable to Chembe because, as outlined earlier, firewood is seldom used for space heating. Another contributory factor is that a minimum quantity of wood is required to establish a fire regardless of household size.

Thus, patterns of fuelwood consumption appear different from those for food where the quantities used are usually directly proportional to the number of individuals. Put another way, there are high fixed costs associated with fuelwood use that seem to favour the maintenance of larger, rather than smaller, households. It is unlikely that patterns of fuelwood use, in themselves, would directly influence desires for high fertility and large household size. However, Hosier (1984) suggests that fuelwood use could be a factor contributing to high fertility and maintenance of large households amongst rural populations. Reporting the results of a nation-wide rural domestic energy consumption survey in Kenya (based on a questionnaire and recall estimates of fuelwood use), he hypothesised that there may be some fixed level of energy necessary to sustain a household under specific socio-economic conditions, such that each additional household member increases fuel consumption less than the previous member.

The current results support these hypotheses. The marginal cost of each household member, up to about eight individuals, is low because each member increases total household efficiency in fuelwood consumption. However, the results do not support theories of unlimited fertility because the fuelwood consumption curve flattens above eight individuals such that the marginal cost of each additional member remains constant and does not contribute to increased household efficiency. Thus there appears to be a level at which households maximise fuelwood efficiency. Below this threshold each individual increases household efficiency and has low net costs. Above this threshold each household member has fixed fuelwood costs associated with their residence within the household.

The role of daughters in fuelwood collection

Figure 5 distinguishes the fuelwood collection activities of women who are assisted and unassisted by their daughters. While there is great variation in the lengths of fuelwood collection trips, women accompanied by their daughters do not appear to select shorter journeys that would be less demanding on their children.

Figure 6 shows the mean size of fuelwood bundle collected by: unaccompanied women, daughters and women accompanied by their daughters. Women assisted by their daughters collect significantly larger loads than women who are unaccompanied (One Way Anova $F = 4.39$, $p = .0133$, Tukey's HSD test separated daughters from their mothers and accompanied women from unaccompanied women at the .05 significance level). This suggests that the accompanying daughter does not reduce a woman's work load. Accompanied women do not use their daughters' labour as a substitute for their own, rather, the presence of a daughter seems to encourage women to collect more wood than their unaccompanied counterparts. Thus, daughters collect additional wood for the household rather than compensating for reduced workloads of their mothers.

Figure 6 also shows the large loads of fuelwood carried by daughters. The mean bundle size collected by daughters is not significantly different from those carried by unaccompanied women. But it is significantly smaller than their mothers', who, as outlined above, carry larger bundles than those unassisted by daughters. Furthermore, when analysed as a proportion of body weight, daughters carry significantly more wood than unaccompanied women and loads equivalent to those of their mothers (One Way Anova F

= 12.31, $p < .0000$, Tukey's HSD test separated assisted women from unassisted women and children at the .05 significance level).

Clearly, accompanied mothers (with regard to the loads carried) and daughters (with regard to the loads carried relative to their body weight) work significantly harder than unaccompanied women. The long term health impacts of carrying heavy fuelwood bundles (and other loads) for long distances are undocumented. However, Korzen (1986) notes lower back problems, known as the 'Kikuyu bursa', for African women who carry heavy loads by the headstrapping method.

The present study suggests that while the frequency with which daughters of appropriate age participate in fuelwood collection is low, their relative contribution to their household, in terms of fuelwood load, is high. On average it appears that mothers with a daughter (or daughters) of appropriate age will be assisted on just half of their wood collection trips (Table 1). The data on households with two daughters suggest that the level of assistance a mother receives may not increase relative to the number of her daughters. These data are consistent with an hypothesis put forward by Cain (1977), that *per capita* productivity, particularly of daughters, may decrease with increasing number of children. However, his rationale, that a finite amount of household maintenance work limits female productivity, is inappropriate here. The labour associated with fuelwood collection is not limiting and there is sufficient opportunity for assistance from several daughters. While the relative level of assistance a woman receives does appear to decrease with increasing number of daughters, I attribute this to the difficulties of wood collection in this area, and believe that it is older daughters who participate more than their younger sisters.

Fuelwood collection requires a steep climb to reach suitable woodland and a difficult walk downhill when loaded (see Chapters 5 and 9). Although other researchers report wood collection from very young ages (e.g. from five years, Cain 1977, Fleuret and Fleuret 1978) such young children were never observed wood collecting in Chembe. I attribute this to the stamina and physical strength required for wood collection in this area which precludes the involvement of young daughters. I believe that younger daughters participate less in fuelwood collection if an older female sibling is in residence and assume greater responsibility for wood collection only when the elder daughter has left the household.

Whatever the frequency of a daughter's participation, the combined effort of a mother and daughter may enable a woman to extend the period between wood collection trips. This was tested by comparing the mean number of days that had passed since the last wood collection trip for women, accompanied and unaccompanied by their daughters. While the interval since the last wood collection trip was longer for women accompanied by their daughters (4.2 days, $n = 12$) than unaccompanied women (3.8 days $n = 166$), the difference was not significant (Mann Whitney U Test $p = .5592$ NS). This may be because daughters do not accompany their mothers on all their wood collection trips. Without data from sequential tracking of women accompanied and unaccompanied by their daughters I cannot test fully whether daughters reduce the frequency at which their mothers collect wood. However, it is clear that women assisted by their daughters bring back more wood in one trip than an unaccompanied woman would bring back in two trips (two mean sized bundles for an unaccompanied woman weigh 53.4 kg, combined mean load for mother and daughter is 57.0 kg). Thus, it appears likely that women assisted by their daughters would be able to collect fuelwood less often.

One explanation for daughters' low frequency of assistance may be that, when not participating in fuelwood collection, they undertake child care or other household maintenance activities. Given the energetic costs to the mother of carrying a baby, a woman may prefer her daughter to provide secure childcare for dependent infants than assist in fuelwood collection, especially with older infants that are too heavy to carry but too young to assist (i.e. children less than ten years old).

Modelling patterns of household fuelwood use

The results from modelling household fuelwood consumption are shown in Figures 7 and 8. It is clear that the marginal costs of each additional child are very low compared with the basic fuelwood required to maintain a household of two adults. The total wood consumption for two adults is approximately 45 kg per week. Yet a family of six consumes approximately 57 kg per week, an additional fuelwood consumption of just 12 kg of wood for four extra people.

It is estimated that a household would use 73 661 kg of wood during its twenty-seven year lifespan. A household of just two adults would use 63 124 kg of fuelwood during the same period. Hence, four children account for just 14.3 per cent of the total fuelwood consumed. Clearly, each child has a very low marginal fuelwood cost, his/her total *per capita* consumption of is 2634 kg during the seventeen years resident within the household.

By comparison a daughter contributes 8635 kg of fuelwood to the household in the seven years in which she assists her mother. This is 81.9 per cent of the fuelwood consumed by all four children and 10.6 per cent of the household's total fuelwood consumption. In the second year of assisting her mother (i.e. by age 12), a daughter's cumulative production exceeds her cumulative consumption and she becomes a net fuelwood producer. Within five years (age 15), she has paid back the total fuelwood costs of both herself and a male sibling. If she assists for seven years, a daughter repays completely the fuelwood used by herself and two of her siblings and 28 per cent of the fuelwood demand of a fourth sibling.

If a second daughter worked as hard as the first, the full energy costs of four children would be met and the mother's basic work load (i.e. the amount of wood required to maintain a household of two adults) would also be reduced. However, the data outlined previously suggest that a mother may not receive extra assistance in wood collection when she has more than one daughter. If the second daughter contributes no fuelwood, the fuelwood cost of two siblings are still repaid through the labour of the elder daughter. However, should the second daughter accompany her mother on just one-third of her wood collection trips, she would contribute 5757 kg of wood which repays all the fuelwood she, and one other sibling, have consumed. Thus, even at this lower level of assistance a daughter returns the combined costs of herself and any one male sibling.

In summary, regardless of the presence or work effort of a second daughter, one daughter assisting on half the fuelwood collection trips pays back the fuelwood costs of 3.25 children. This exceeds the fuelwood costs of any two brothers who do not assist in this task. Similarly, one daughter assisting on just one third of fuelwood trips pays back her fuelwood costs and those of one male sibling. The ability of daughters to be net fuelwood producers seems paradoxical given the observed low frequency of their assistance in fuelwood collection. However, the high fixed costs for household fuelwood use and the strong effect of household size on energy efficiency mean that daughters are able to pay back their fuelwood costs even when they participate in just one half or one third of fuelwood collection trips. Clearly, these patterns of fuelwood consumption differ sharply from the labour associated with food production (see, for example Kaplan 1994). For resources such as food, where the amount required increases in proportion to the number of people resident, children would have to contribute significant labour to the household to repay their costs.

Conclusions

This chapter has examined patterns of wood collection and use by households living within LMNP. The findings are summarised and integrated in the following sections.

Nursing women as foragers

The present study indicates that nursing women are as efficient foragers as non-nursing women: their load sizes and foraging times appear unaffected by the presence of a baby. These findings differ from those among hunter gatherer groups (see Hurtado et al. 1985, 1992, Blurton Jones et al. 1989) which suggest that nursing women are often less efficient foragers. Malawian women, like the Tamang of Nepal (see Panter-Brick 1989), seem able to integrate child care into their work activities. By feeding babies during the rest periods associated with their work women are able to assume normal workloads.

Various factors, such as the level of dependence on female labour, age of the infant, perceived dangers in the environment and availability of alternative caretakers appear important in female foraging decisions. Fuelwood is a domestic requirement and its collection in LMNP is undertaken exclusively by women. While their babies need frequent feeding, nursing women have little option than to have their babies accompany them on foraging trips. The carried babies are young (less than one year old) and relatively light. Thus, the additional weight of the baby (mean 7.7 kg) does not appear to affect the bundle size collected. Among hunter gatherers, women are observed to carry older children (up to age two and four years amongst the Hadza and !Kung respectively, Blurton Jones et al. 1989). It is in these groups, where the carried infant is substantially heavier than these Malawian infants, that reduced foraging efficiencies are recorded.

Brouwer et al. (1989) suggest that to economise on time, women try to carry as much wood as possible in one load. Thus, the heavy bundles (mean size, 31.0 kg) carried by fuelwood collectors may be 'economically rational' given the steep gradient and the long distance travelled between the village and the woodland (cf. Blurton Jones et al. 1989, see Chapter 9). By carrying their babies only when they are very young, nursing women are able to maintain fuelwood loads equivalent to non-nursing women. It is unlikely that women could continue to collect such large loads as the infants grow and get heavier.

However, as the infants age they do not require frequent feeding and can be left for duration of a wood collection trip (mean journey time four hours). If there is no risk to the baby, it is energetically less demanding for the mother to leave her baby with caretakers in the village. This enables her to maintain economically rational collection of large loads of fuelwood.

Levine (1988) notes that childcare is seen as a comparatively non-demanding and unspecialised activity which can be undertaken by a range of individuals (such as post-reproductive women or older children, see Turke 1988). In one study, among the Kipsigis of Kenya, Borgerhoff Mulder (1985) described caretakers as young as 4.5 years old and suggested that non-maternal care was of equal quality to that provided by the mother (see Hames 1988 for a discussion). However, it seems unlikely that a baby would receive adequate care if it was exposed to prolonged supervision from young individuals.

By carrying children only when they are young and by utilising caretakers when the child is older, women appear able to have wood collection patterns unaffected by their nursing condition. It appears that the availability of childcare in the village (particularly resident grandmothers) enables nursing women to pursue efficient foraging strategies in the absence of male provisioning and where there is total dependence on female labour for collecting this resource.

Daughters participation in fuelwood collection

The frequency of assistance a mother receives from her female offspring suggests she does not exploit them for their labour. Although one daughter may pay back the energy demand of 3.25 children she is not working as hard as she might. For example, a daughter assisting her mother on half her wood collection trips reduces the maternal work load by just over 10 per cent. Yet by insisting that daughters work more often a mother could substantially reduce her work load. Furthermore, the level of assistance a mother receives does not seem to increase in proportion to the number of her daughters. It is interesting that I observed only one case where a daughter collected fuelwood unaccompanied by her mother, who was sick. Clearly, daughters supplement, rather than substitute for, maternal labour. This may be a 'reproductive decision' in that a mother decides not to burden a child with excessive wood collection. Moreover, a daughter's participation in wood collection may provide an opportunity for training in an activity which she will have to undertake for herself when she manages her own household.

Direction of inter-generational wealth flows

This study has shown that daughters make a positive contribution to the household through their labour associated with wood collection. Analysis of this one subsistence activity suggests that the net transfer of resources from female offspring to their parents is positive. This supports Caldwell's (1983) wealth flows theories of fertility which states that in pre-transition societies the net value of inter-generational wealth flows is upward. Wealth flow and evolutionary theories of fertility appear, as outlined previously, to have directly opposing predictions regarding the direction of inter-generational wealth flows (see Kaplan 1994). However, while supporting wealth flows theories of fertility, these findings are not inconsistent with evolutionary theories. Although the labour of female offspring in fuelwood collection repays their fuelwood costs (and those of male siblings), it is clear that daughters are not being exploited for their labour. The high fixed costs associated with fuelwood use ensure that daughters are able to make a positive contribution to the household at a relatively low frequency of work effort. Hence, as daughters are not being utilised solely for their labour, these findings do not conflict with evolutionary theories of fertility which suggest that parents should invest in, and not exploit, their offspring (cf. Kaplan 1994).

Gender and the role of children in subsistence and economic activities

The rigid division of labour by sex in many communities means that male and female offspring undertake different tasks. Cain (1977) distinguished subsistence (household maintenance) activities from economic (productive) work. In his study village in Bangladesh (and elsewhere in the developing world), girls have little access to productive work. Cain concluded that 'male children have to produce enough to offset their sisters' net consumption'. By analysing economic activities, he showed that boys were able to 'pay back' their own costs and that of one sister by age 22. His analysis included only economic work because this was easier to convert to monetary value using local wage rates than subsistence activities. However, he noted that 'girls spend roughly the same total time working as boys at each age, [although] they spend uniformly less time in directly productive work' (Cain 1977). His paper concluded that high fertility and large numbers of surviving children are economically rational propositions. Yet in a later paper he reports 'because of the division of labour by sex, girls are much less productive than boys' (Cain 1982). However, by valuing male dominated economic activities only and using a narrow definition of production, it is not surprising that he found this result.

While it may be more difficult to quantify labour in subsistence tasks, such activities should be evaluated as they facilitate the operation of the household as a productive unit. The present study has analysed the role of women and their daughters in one subsistence activity, fuelwood collection, which is not undertaken by males of any age. Daughters pay back their cumulative fuelwood costs and those of 2.25 other siblings i.e. they cover the costs of more than two male offspring who do not participate in this task. Among South American hunter gatherers, children of both sexes participate in subsistence foraging. Kaplan (1994) shows that during childhood and adolescence, Hiwi girls produce the same as boys, while Machiguenga and Ache girls produce more food than boys. Similarly, Nag, White and Peet (1978) and De Tray (1983) show that girls contribute more productive hours than boys. It is clear that female labour is substantial and equals or exceeds male productive output with regard to household maintenance tasks.

Gender preference, particularly son preference, is believed to sustain high fertility in developing countries (Rahman and Da Vanzo 1993). While many studies suggest high levels of son preference, it tends to have been overlooked that parents may also prefer daughters. Rahman and Da Vanzo (1993) present demographic data from Bangladesh suggesting that parents, particularly mothers, desire at least one daughter. They attribute this to the greater contribution girls make to the household compared with boys. They suggest that in rural Asian societies, girls assist in household maintenance tasks and subsistence farming, which are typically the domain of women. The findings of the present study highlight the labour contribution that a daughter makes to the household in terms of fuelwood collection, yet this is just one of the many tasks in which daughters participate. These findings suggest that women in this Malawian society would also desire at least one daughter.

In Cain's (1977) study, children of both sexes worked a similar number of hours. Re-analysis may show that girls 'pay back' their own costs (and those of their brothers), in the subsistence activities in which female labour dominates, even though they are unable to 'pay back' their costs in economic work because they don't have access to this type of employment. Without valuing subsistence labour, Cain's work implies that the productive potential of sons is greater than for daughters because they are more likely to repay their parents for the resources expended in rearing them (see Hrdy and Judge 1993). While it is true, that male, rather than female, children may represent a means of accumulating economic wealth within their parents' lifetime, it would be misleading to conclude that boys are more productive than girls without assessing the net contribution that children of both sexes make to economic and subsistence activities.

While this study demonstrates that girls have lower net fuelwood costs than boys, fuelwood is only one limited aspect of resource use and male offspring may have benefits not measured here. In Chembe village, boys participate in economic activities associated with the tourist industry. Because boys are more likely to attend school than girls, they have better English to converse with tourists visiting the National Park (Abbot 1995). However, boys do not assist in fishing which is the major economic activity in the village. This is undertaken by adult males because only they have the strength to haul in the nets (Smith 1993a). There are also few opportunities for hunting within the National Park (see Chapter 4) which is a traditionally male-dominated activity. Both males and females of all ages assist in agricultural labour. Thus, my personal observations suggest that during childhood, girls contribute substantially to household maintenance tasks and may be more productive than boys in this society.

Re-examination of subsistence activities

This study has demonstrated that the efficiency of fuelwood use varies with household size. It emphasises that the pattern of use of a resource influences how the work load associated with it increases as a function of household size. Kaplan (1994) analyses child labour in terms of food acquisition but acknowledges that children undertake other chores. However, he suggests that children spend little time in productive and domestic labour, noting that adults of both sexes appear to spend much more time in domestic activities than do children. But the present study suggests that a low frequency of assistance by children may make a substantial contribution to tasks with high fixed costs, i.e. where the amount of labour required does not increase in direct proportion to the number of individuals. Examples of tasks with high fixed costs include, collection of fuelwood or water, childcare and housework (such as cooking and cleaning).

Therefore, to analyse the net contribution children make to a household, it is important to evaluate a range of activities with high and low fixed costs (including both economic and subsistence activities). One cannot isolate one task, either food or fuelwood collection, to analyse the net cost of children because patterns of use of the resource itself determine how much (or how little) children have to participate to pay back their costs. While Kaplan's (1994) study showed that children supply less than one quarter of their food requirements, their assistance on other chores, albeit at low levels, may be sufficient for them to pay back their cumulative costs.

Implications for reproductive decisions and family size

The present data indicate that a girl repays her cumulative fuelwood costs, and those of up to 2.25 other siblings, through her labour in fuelwood collection. However, because the level of labour a mother receives does not seem to increase in proportion to the number of her daughters, the data do not support the theory that child labour is a driving force behind the high fertility of developing countries. In addition, the data on household fuelwood efficiency suggest that at a household size of more than seven or eight individuals, residents of either sex become burdensome. Instead of increasing household fuelwood efficiency, each additional individual has a fixed *per capita* cost which does not contribute to total household efficiency.

By having one daughter, the fuelwood demand of 3.25 children is met at no energetic expense to the mother. However, there is no evidence for biased parental investment towards daughters within the village (see Mace *in press*). Nor would I expect to find this because fuelwood provision is by no means the only criterion and anyway I have shown that the productive potential of daughters appears to decline with their increasing number. With a mean family size of four offspring, probability suggests that women will have (at least) one daughter and there appears to be a reduced incentive for women to have more than one daughter for assistance with fuelwood collection. Furthermore, I would not expect this one subsistence activity to influence patterns of parental investment (see below).

I do not have data to test whether a daughter's assistance in fuelwood collection, and the consequent reduction in a mother's energetic burden, results in reduced inter-birth intervals, as would be predicted from evolutionary theory (cf. Turke 1988). However, I would not expect fuelwood collection to have a direct impact on fertility. As one subsistence activity, it is unlikely that women would make reproductive decisions based on fuelwood collection alone. Further detailed observational data are required on child labour in a range of subsistence and economic activities to understand reproductive decision making. In particular, theories of fertility would benefit from an increased understanding of how patterns of child productivity vary with the number of offspring of working age.

The present study indicates that female children are productive and make a net contribution to the household economy. It also demonstrates the importance of local socio-ecological factors (cf. Hurtado et al. 1992) in female foraging decisions. Fuelwood collection in LMNP is an arduous task for which there is total dependence on female labour. Nursing women appear as efficient foragers as non-nursing women. By carrying their babies only when they are very small, and relying on alternative child care within the village, women are able to maintain collection of large loads of fuelwood that appear 'economically rational' given the local terrain. The energetic costs of fuelwood collection are discussed further in the next chapter.

Chapter 9

Foraging[1] decisions: the role of time, energy, habitat and risk.

Summary

The previous chapter explored domestic fuelwood collection in terms of the household division of labour. It demonstrated that this task is female dominated, undertaken by women accompanied by their daughters. This chapter explores the decision making in domestic fuelwood collection, in terms of the destination of wood collector groups and the load size collected. Using a cost-benefit analysis, various parameters are explored to determine their influence in wood collection decisions. Given the demanding nature of wood collection, time and energy are explored as determinants of wood collection practices. Furthermore, the destination of wood collectors is examined in relation to the risk posed by scout patrols and the availability of different woodland habitats. An understanding of the factors that influence the decision making process in wood collection provides a sound basis for woodland management.

Introduction

Since the mid-1970s, behavioural ecology approaches have to led to the development of foraging theories to explain the feeding behaviours of a wide range of animal species (see Stephens and Krebs 1986). Behavioural ecology is founded on the premise that individuals behave so as to maximise their reproductive success. Optimality modelling is the main tool used to analyse the costs and benefits of alternative courses of action that an individual may take. Costs and benefits are ultimately measured in terms of fitness (survival and reproduction) but more proximate measures, such as energetic expenditure or procurement rate, may be used to examine factors which influence decision making.

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[1]Foraging, the act of searching for food or provisions, Collins Concise Dictionary, 1989.

Any optimality model or cost-benefit analysis consists of three components: *the currency*, the unifying measurement of costs and benefits, *the constraints*, fixed environmental or physical checks on behaviour, and the *decision variable*, the individual's choice of behaviour. The simplest model considers an individual forager who encounters patches or prey sequentially. The decision is whether to eat or search. These are assumed to be mutually exclusive actions. For the patch model, the decision is how long to stay in the patch before moving on to the next one (e.g. Cowie 1977). Because there are finite resources within a patch, the animal's marginal rate of return decreases the longer it stays in the patch. A graph of load plotted against search or patch time is known as the loading or gain curve. The slope of the curve negatively accelerates with progressive patch exploitation, such that the animal receives 'diminishing returns'. Derived from the marginal value theorem, the model predicts that the animals should leave the patch, and move onto another, when the intake rate in any patch drops to the average rate for the habitat (see Stephens and Krebs 1986 for a full discussion).

One elaboration of this simple model incorporates simultaneous, rather than sequential, encounters of patches or prey. This better reflects the way in which many animals forage and encounter resources. In addition, central-place foraging models have been developed to examine the travel costs imposed by foraging for a resource positioned at some distance from the individual's home base. These models have been used primarily to study birds returning to feed their young at nests (e.g. Bryant and Turner 1982) but are equally applicable to human foraging. The model considers a forager who travels to a patch, captures prey and returns to the central place. As outlined above, the patch has a negatively accelerated gain function, and the forager faces a trade-off between in-patch foraging efficiency and travel time to the central place. Using the marginal value theorem, the model predicts that optimal load size should increase with distance from the central place.

Other models make a distinction between foragers who hunt for single prey ('single-prey loaders') *versus* those who carry many items at once ('multiple prey loaders'). For multiple prey loaders, it is predicted that the efficiency of search and capture decreases as the load increases. The decrease in rate of prey capture is not through depletion of the patch, rather, the increasing load impedes the ability of the individual to acquire further prey (e.g. Giraldeau and Kramer 1982).

Foraging theory has proven to a powerful analytical tool in the study of behaviour and ecology. Many studies, on a range of species, have shown animals to forage as predicted from foraging theory (see overviews by Stephens and Krebs 1986 and Krebs and Davies 1991). While most research has concentrated on food acquisition, the theory has been applied to other resources (for example, water collection in a Japanese paper wasp, Kasuya 1982) and other activities, such as reproductive decisions in mate searching and copulation (Parker 1978, in Krebs and Davies 1993). More recently, behavioural ecology has been applied to human populations, to determine how ecological and social factors affect behavioural variability (see Smith 1983, Smith and Winterhalder 1992). Optimal foraging theory has been used extensively to examine and explain human diet choice. Central place foraging is used by Metcalfe and Barlow (1992) to investigate the optimal trade-off between field processing and resource transport in ethnographic settings. Hawkes et al. (1982) investigated whether selective resource exploitation served to maximise caloric returns per time spent foraging. Their study, and others based on the simple prey choice model (for reviews see Borgerhoff Mulder 1991, Kaplan and Hill 1992), have indicated that human foragers maximise return rates within classes of food (for example, proteins or carbohydrates).

However, deviations occur from the predictions of foraging theory. Foragers appear to modify short-term patch use to parallel changing return rates or environmental conditions, both of which have been difficult to quantify (Beckerman 1983). Hill (1988) employed indifference curves to refine foraging models and examine the role of macronutrients, rather than caloric gain, in foraging decisions. Such models help to explain the low energetic returns (i.e. non-rate maximising the return of energy) in hunting by different South American foraging groups (the Ache, Cuiva and Yora) and the Mbuti of Zaire. These refinements have helped counter criticism that foraging models are too simplistic and, by failing to incorporate the complexities of the foraging process, are biologically unrealistic (see Smith 1983).

By its nature, a model *is* a simplification of the 'real' world. There is a trade-off, however, between the level of precision and realism in any model and its universality and use in representing the elements of the situation modelled (cf. Smith 1983). While models may lack detail by characterising only a few, of many, variables that may influence behaviour, the advantage of quantification and use of a formal model is that the assumptions surrounding the hypotheses are explicit. This enables rigorous testing and refining of models, allowing the main factors that influence decision making to be isolated from a range of variables.

Preliminary Analysis

Most foraging studies amongst humans have investigated the hunting and gathering of wild food items. Here I apply a cost-benefit approach to women's collection of fuelwood, to try and identify the factors that underpin their foraging decisions. I identified four possible factors with which to evaluate women's wood collection behaviour: time, energy, risk and habitat. I will start by justifying the use of these currencies.

Time and energy are commonly used to evaluate decision variables in behavioural ecology (see Stephens and Krebs 1986). Time is a relevant and useful variable because many studies document the heavy work loads undertaken by women in the developing world and indicate that women often work longer hours than men (e.g. Ellis 1988, Boserup 1989). In a review of rural time allocation studies from a range of geographical areas, Ellis (1988) reports that the contribution of men to the household varies from 15 minutes to 1.5 hours a day, while that of women ranges between 5 and 7 hours. Kandyoti (1987) notes that a growing number of time-budget studies indicate that household maintenance tasks, such as fuel collection, water fetching, and food processing and preparation occupy a large proportion of working hours. Recent work by Bryceson and Howe (1993) on rural household transport suggests that Tanzanian women spend over 300 hours *per annum* on wood collection. Data from the previous chapter suggest that Malawian women in LMNP spend in excess of 380 hours *per annum* collecting fuelwood (96 trips *per annum* of a mean length of 241 minutes per trip). Thus, time may be a limiting factor for women and it is hypothesised that they may try to minimise the time allocated to wood collection.

Similarly with energy, many studies in developing countries have linked work demands with nutritional status and shown seasonal energy deficits (e.g. Batliwala 1982, Bayliss-Smith 1990). Furthermore, from their study of gender differences in the time and energy cost of regular domestic chores in Zimbabwe, Mehretu and Mutambirwa (1992) found that fuelwood collection was one of the tasks that exacted the heaviest burdens on women (see also Batliwala 1982 for a similar study in India). Wood collection within LMNP requires a steep climb from the village (at lakeshore level, 500m) to reach the woodlands in the hills, which peak at 1150m. Hence, women may be concerned with minimising their energetic expenditure in wood collection.

As outlined in Chapter 2, wood collection without prior purchase of a permit is an illegal activity within the National Park. Scouts patrol the woodland to detect illegal wood collectors. Most women claim to be unable to afford a permit each time they collect fuelwood. Among tracked wood collectors, less than 20 per cent had purchased a ticket. Even this is likely to over-estimate the level of legal collection as women are likely to claim to have bought a ticket when they had not done so. If detected by scout patrols, illegal wood collectors risk penalties, which range from warnings or fines, to the more severe confiscation or burning of bundles.

Studies on illegal activity have shown that the probability of being caught and convicted is a strong deterrent to illegal activity (see Milner-Gulland and Leader Williams 1992 and Leader Williams and Milner-Gulland 1993). Their research in a protected area in Zambia modelled the relationship between the risk of detection and penalties for illegal exploitation of wildlife. They show that the probability of detection is a 'highly significant factor in the poacher's decision to hunt'. Women wood collectors may be similarly influenced in their foraging activities by the risk imposed by law enforcement penalties for illegal collection. Thus, wood collectors may attempt to reduce their risk of encounters with scout patrols.

Women show preference towards fuelwood of specific species and size classes. Selection preferences have been examined previously in Chapters 4 and 6. Fuelwood bundles comprise a range of different species including both hardwoods and lighter woods. This is because hard wood species are difficult to cut and heavy to carry. In addition, different species have different uses. Fast-burning species are used to start fires and hardwoods are used to maintain the fire for cooking. Generally however women seem to prefer hardwood species because of their superior burning properties: they burn for longer and do not produce smoke. I hypothesise that women may select specific areas in the woodland which contain a range of suitably sized trees of the preferred species (see Chapter 5 for detailed habitat descriptions). Hardwood species (such as *Brachystegia* spp. and *Combretum* spp.) are the canopy dominants of *miombo*. They occur less frequently in the disturbed, sparse (*chipya*) woodland found close to the village. This contains hardy, fire-resistant, fast growing species (such as *Diplorhynchus condylocarpon*). While *chipya* species are used as firewood, many are not preferred because they burn quickly and produce a lot of smoke. Thus, in this analysis, habitat type is used as a simple, proxy measure of wood quality. Closed canopy *miombo* is hypothesised as the best habitat for wood collection because it contains the preferred hardwoods.

Thus, I predict that women would attempt to:

- Maximise their rate of wood collection
- Maximise the energetic efficiency of wood collection
- Minimise their risk of encounter with law enforcement patrols or
- Maximise the quality of wood collected through selection of appropriate woodland habitats.

It should be noted that these variables are not mutually exclusive. For example, by minimising the time taken to collect a bundle of firewood women also reduce their risk of being caught by Park staff. Similarly, by minimising energetic expenditure, women may also reduce their time costs. Indeed, preliminary model development (Abbot 1993) suggested that strategies to minimise either time or energy in wood collection would have similar outcomes to the extent that observational data would not distinguish between the two strategies.

Methods

Focal group sampling (Altmann 1974) was used to examine the wood collection behaviour of women from Chembe. The sampling procedure is described more fully in Chapter 8. Forty two fuelwood collection groups were tracked from Chembe village. Because of the large size of the village (4 km in length), it was important to track women from households on the edge of the village (close to the woodland) as well as those who lived more centrally (and were positioned further from the woodland). Fuelwood collection groups were therefore classified as 'near' or 'far' depicting their proximity to the resource base.

Travel times and distance walked were measured for walking on level ground, uphill and downhill. Gradient was measured with a clinometer. Distance was measured using a pedometer and verified using map estimates of the distance covered. Search time was also recorded. This is defined as the time from when women reached the wood collection base until they loaded bundles on to their heads to return home. This included time for wood collection, tying bundles and resting. A sample form for focal group observation is included in Appendix 10.

Using a 1:50 000 map of the area the National Park was divided into 1 km^2 grid squares. These were used to record the destination of the wood collection groups. In addition, the habitat type of each of the grid squares was determined using the most recent set of aerial photographs (see Chapter 6). Three habitat types were discerned: sparse woodland, mixed woodland (grid squares containing both sparse woodland and closed canopy woodland) and closed canopy woodland. The risk of penalties imposed by law enforcement was analysed using records of scout patrols over an eight month period (October 1993 - May 1994). For each patrol, scouts recorded their route (indicating the grid squares patrolled) and any encounters of illegal activity. A sample form for Woodland Patrol Reports is included in Appendix 11.

Using methods outlined by Bell (1984) to monitor illegal activity and law enforcement, patrolling effort was estimated from the frequency with which grid squares were patrolled per unit of time. This is a simple method of estimating patrolling effort. Its disadvantage is a potentially uneven detection of illegal activity within a patrol square: where a patrol passes along one edge of a grid square, it may not detect illegal activity within the whole grid square. However, the small size of grid squares used to monitor scout patrols at LMNP (1 km^2, compared with the 5 km^2 grid squares of most, larger Malawi National Parks) help to ensure that patrols would detect illegal activity across the whole of the grid square. Furthermore, it is difficult for wood collectors to conceal their activities from any patrols in the vicinity because of the noise generated in cutting wood. Hence, this method is thought to provide a reliable assessment of the risk of law enforcement penalties for women wood collectors.

Analysis

A formal model is not developed in this analysis because the results (see below) suggest that profitability (load size) does not increase with distance from the resource base. Thus, this chapter takes a cost-benefit approach to examine a range of variables that may influence patterns of resource collection.

Forty two wood collection groups were tracked during the study but some of the analyses show a smaller sample size. For example, estimates of the energetic expenditure of wood collection are undertaken on only thirty-two of the groups. This is because insufficient data were recorded when tracking due to equipment failure, either with the clinometer or pedometer (hence data on the distances walked on the level *versus* on a slope or the gradient could not be collected). Sample sizes are shown for all the results. Bundle weights are calculated as means for the group. Journey length includes the time spent travelling to, and from, the patch but does not include search time, which was recorded and analysed separately.

Unless otherwise stated, parametric tests were used when data were shown to be normally distributed (i.e. Index of Skewness ≤ 1 or conformed to a normal probability plot and Shapiro-Wilk's and K-S Lilliefors tests for normality, Norusis 1995, Sokal and Rohlf 1995). Where data deviated from normality or for tests with a small or uneven sample size, non-parametric methods were used.

The predicted energetic expenditure for wood collection in each of the grid squares was estimated by adapting Brannan's (1992) refinements of the model developed by Jones and Madsen (1989). Brannan's model incorporates measures to estimate the energetic costs of travel according to: distance travelled, the gradient, the terrain covered and the weight carried. Using a 1:50 000 map, the distance from the village to each grid square was calculated, measuring separately the distance walked on level ground and the distance walked uphill. The mean gradient for each grid square was calculated from the contour lines. Because the energetic cost of walking varies with terrain (Soule and Goldman 1972), terrain coefficients for dirt road (assumed for distances covered on level ground) and light brush (assumed for distances covered in the woodland) were used. Energetic costs were calculated for a load size of 27 kg of fuelwood, which is the mean load size carried by tracked women (see Chapter 8). The additional caloric costs per kilometre travelled at gradients were estimated from equations provided by McDonald (1961). The formula used to estimate E, the energetic expenditure in return travel to each grid square is: formula used to estimate E, the energetic expenditure in return travel to each grid square is:

$$E = \underbrace{\sum_{i=1}^{n} (t_i k_i) f_i}_{\text{Energy Outward}} + \underbrace{\sum_{i=1}^{n} (t_i ((w_i l_i) + l_i)) f_i}_{\text{Energy Return}}$$

where k is the caloric cost of walking each kilometre to the resource base

l is the caloric cost of walking each kilometre back to the village

t is the terrain co-efficient

w is the % increase in caloric expenditure due to the excess weight of the load.

The summation sign allows for variability in costs per unit of distance for gradient and terrain, while f denotes the number of kilometres the costs remain constant.

The energetic costs of wood collection in the patch were excluded from these analyses as they were assumed to be fixed costs: patch time did not vary in any predictable way with distance from the resource base or distance travelled (see Discussion). The predicted time costs for accessing each grid square were estimated using a walking speed of 3 km per hour (cf. Brannan 1992).

The estimated energetic expenditure of tracked wood collection trips was calculated using the same formula. However, distances covered on level ground and at a gradient were recorded directly using a pedometer (verified with map estimates). The mean load size collected by each group was determined and used to estimate energetic expenditure when loaded. Appendices 12 and 13 contain the raw data for undertaking analyses of the time and energy expended in wood collection in each grid square and by each of the groups of tracked wood collectors.

Results

The results of the present analyses are shown in Figures 1 - 14. Analysis of the time and energy costs of wood collection show similar results. Figures 1 and 3, respectively, show a significant negative correlation between the frequency with which women collect wood in a grid square and the predicted time and energy cost in accessing that area. The time costs of wood collection were further tested by examining how the rate of wood collection varied with journey length. Figure 2 shows that by making long journeys women (living both near and far from the resource base) reduce their rate of wood collection. The predicted energetic efficiency of wood collection shows a similar pattern: groups of wood collectors (living both near and far from the resource base) have reduced energetic efficiencies at longer distances (Figure 4).

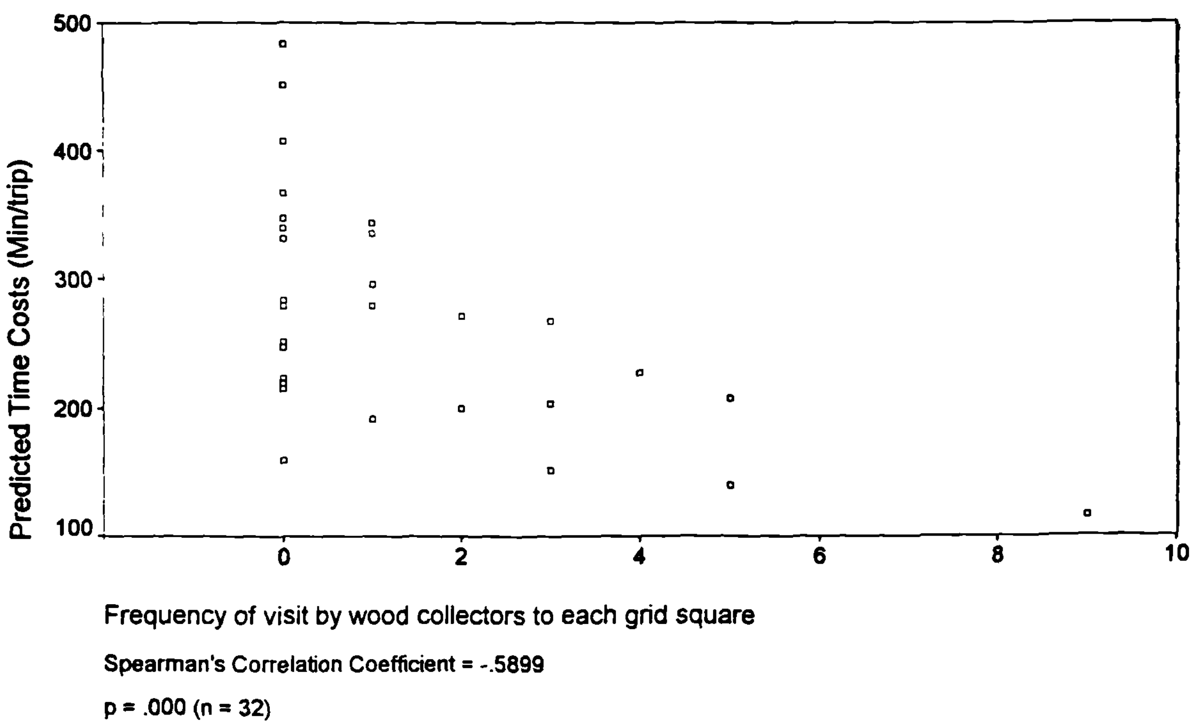


Figure 1. Predicted time costs for wood collection in each grid square and the frequency of visit by women.

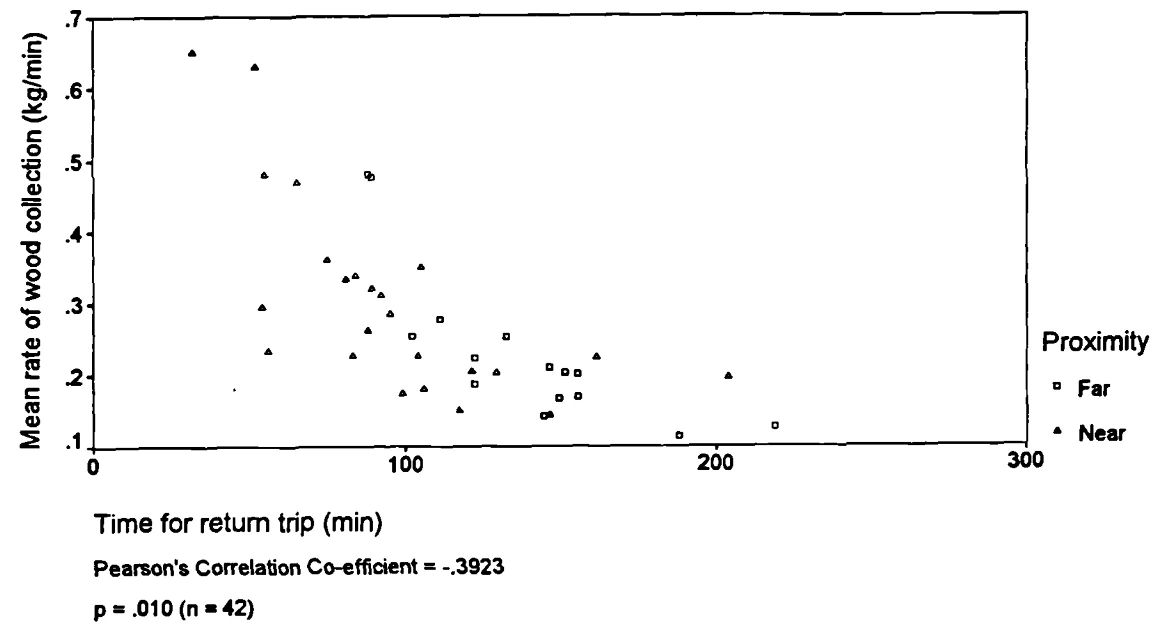


Figure 2. Rate of wood collection.

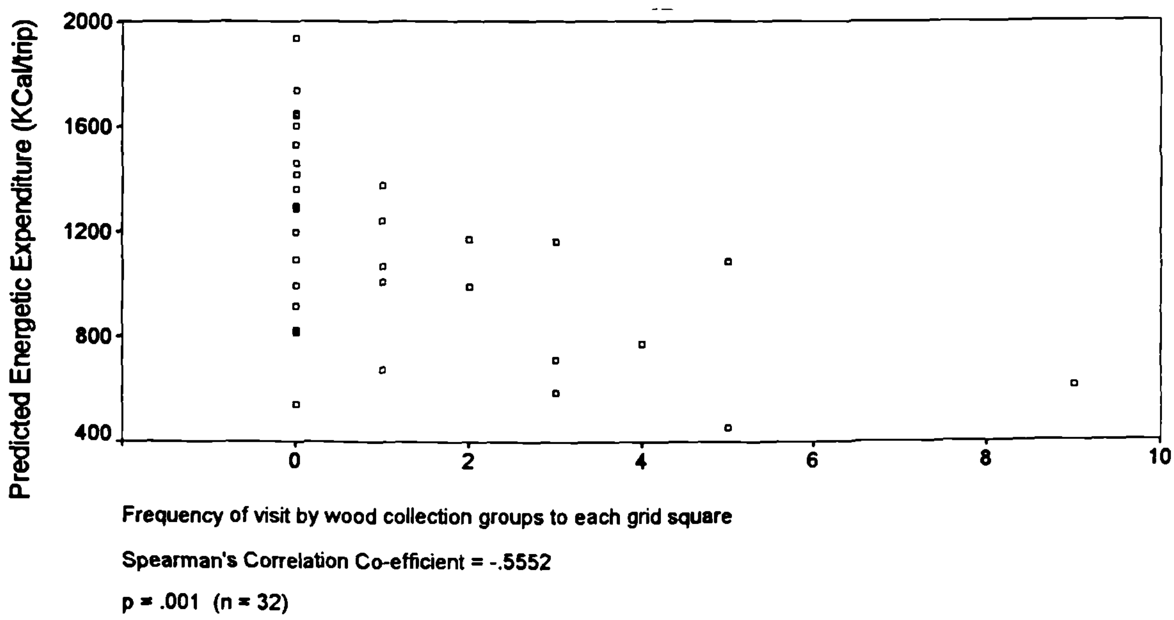
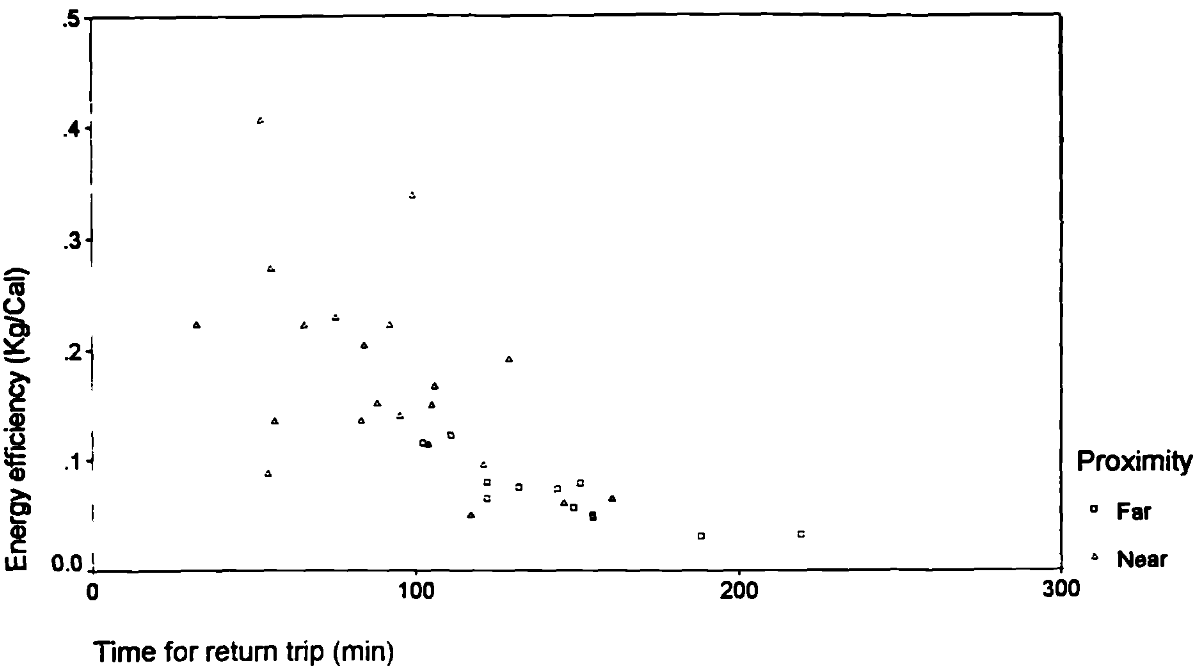


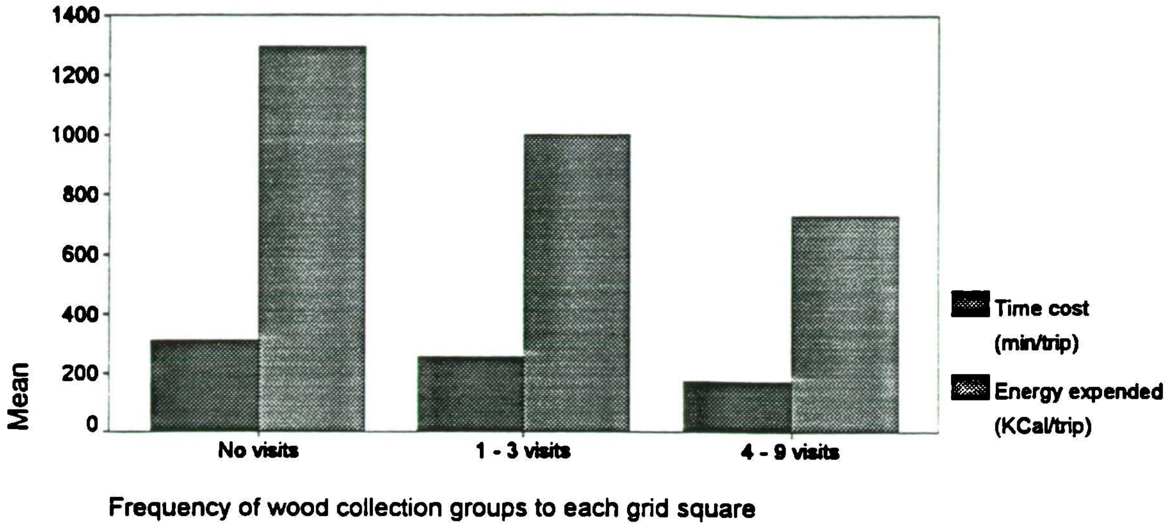
Figure 3. Predicted energetic expenditure for wood collection in each grid square and the frequency of visit by women.



Pearson's Correlation Coefficient r = -.70 (n=33) p = .000

Figure 4. Energetic efficiency of wood collection.

Figure 5 partitions the data set into three categories: grid squares never visited by wood collection groups, those visited intermediately (1-3 visits) and those visited frequently (4-9 times). The mean time and energy expended per wood collection trip for each category of grid squares is plotted. Analyses of variance (non-parametric because of the uneven sample size in each of the categories) demonstrate a significant difference in the mean time cost and energetic expenditure for wood collection in each category of grid squares.

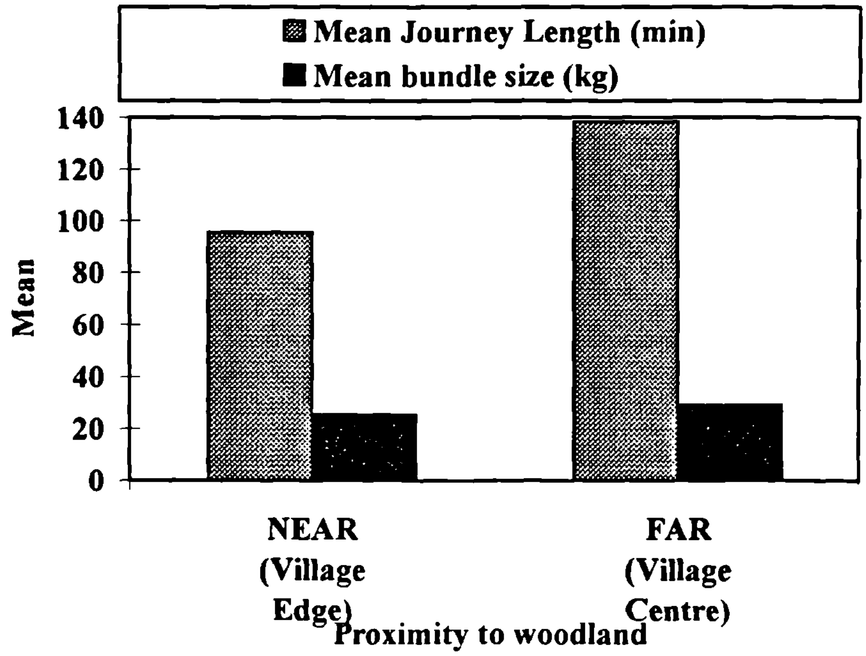


Kruskal-Wallis One Way Anova (corrected for ties)

Time p = .0109 Energy p = .0111 (two tailed, df = 2, n = 32)

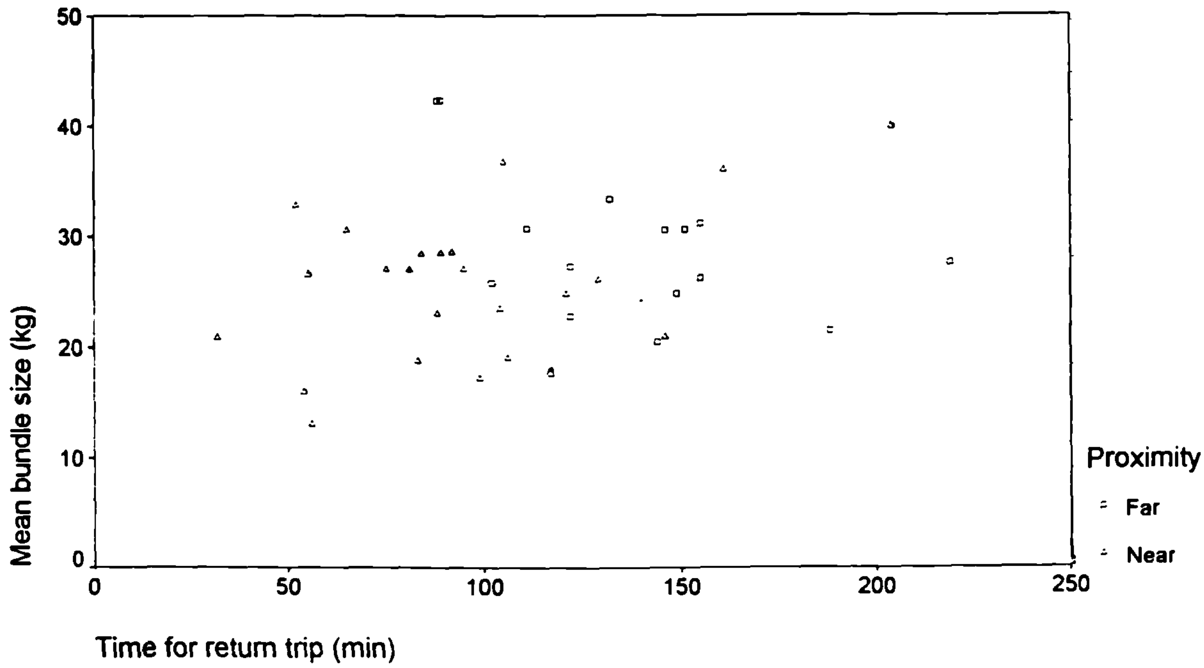
Figure 5. Comparison of the energetic and time costs of wood collection and the frequency of visit by wood collectors.

The effect of distance on load size was examined by comparing the mean load size collected by groups of women who live at two distances ('near' and 'far') from the resource base. Figure 6 shows that while women who live centrally in the village have significantly longer journey times than women who live on the periphery of the village, there is no significant difference in the load size gathered by the two groups. Similarly, a plot of mean bundle weight against journey time, shows that there is no significant association between the two variables (Figure 7).



Mann-Whitney tests. Sample size: near (n=24), far (n=15).
Mean journey length (minutes): Near 95.54, Far 138.20. 2 tailed p = .000
Mean bundle weight (kg): Near 25.39, Far 29.18. 2 tailed p = .100

Figure 6. Proximity to woodland and load size collected.



Pearson's Correlation Coefficient r = .2868 (n=42) p=.066 NS

Figure 7. Bundle size collected and journey time.

Furthermore, by travelling further, groups of women are not able to reduce their patch residence times. Because there is no significant difference in the patch times of groups of women living near and far from the woodland (Mann-Whitney 2-tailed test, corrected for ties, $p = .242$ NS, $n = 39$), the data are pooled in this analysis. Patch residence times are calculated per unit of wood collected to control for any effect of distance on load size. Figure 8 suggests that there is no significant association between patch residence time per kilogram of wood collected and journey time. The result is the same if just patch time is plotted against journey time (Pearson's Correlation Coefficient = .0000, $p = 1.000$ $n = 42$).

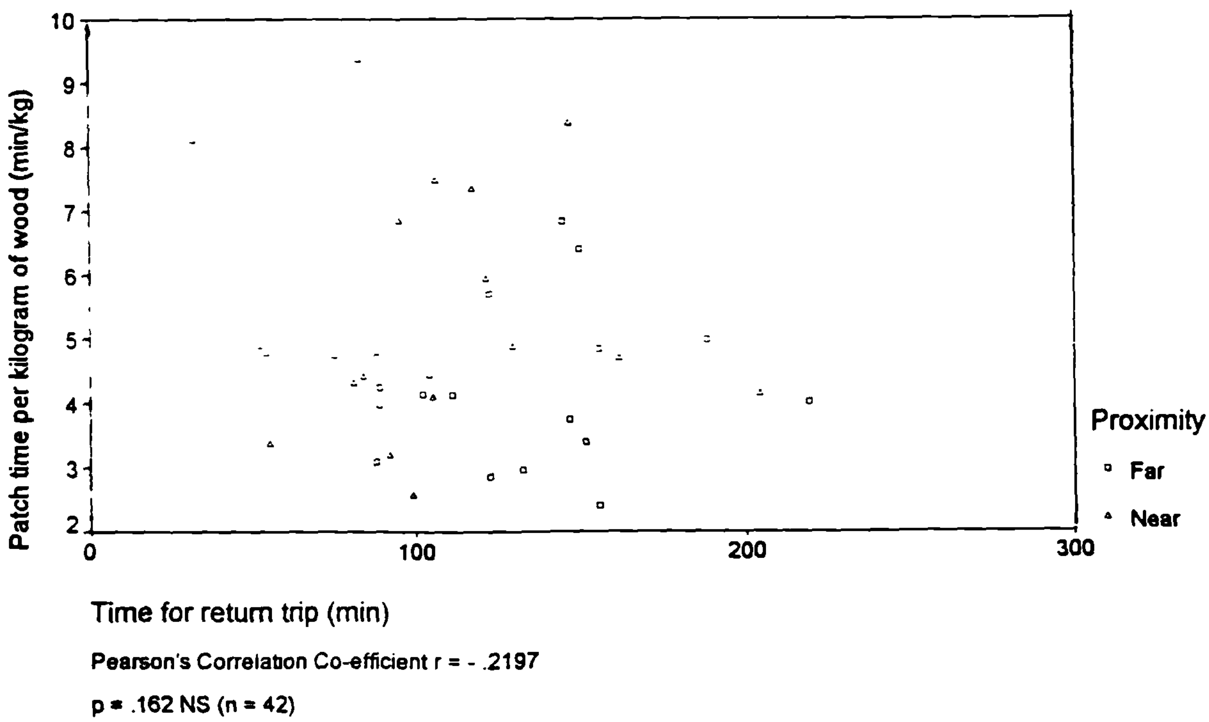


Figure 8. Patch and journey time for women wood collectors.

Figure 9 investigates the role of law enforcement activities on patterns of wood collection. This suggests that fuelwood collectors and scout patrols target the same grid squares. Figure 10 indicates the frequency with which different penalties are imposed by scouts when they encounter women collecting wood illegally. On more than half their encounters with illegal wood collectors, the penalty imposed was a warning. Figure 11 suggests that there is a strong, negative correlation between the energetic cost of accessing each grid square and the frequency of visit by Park patrols.

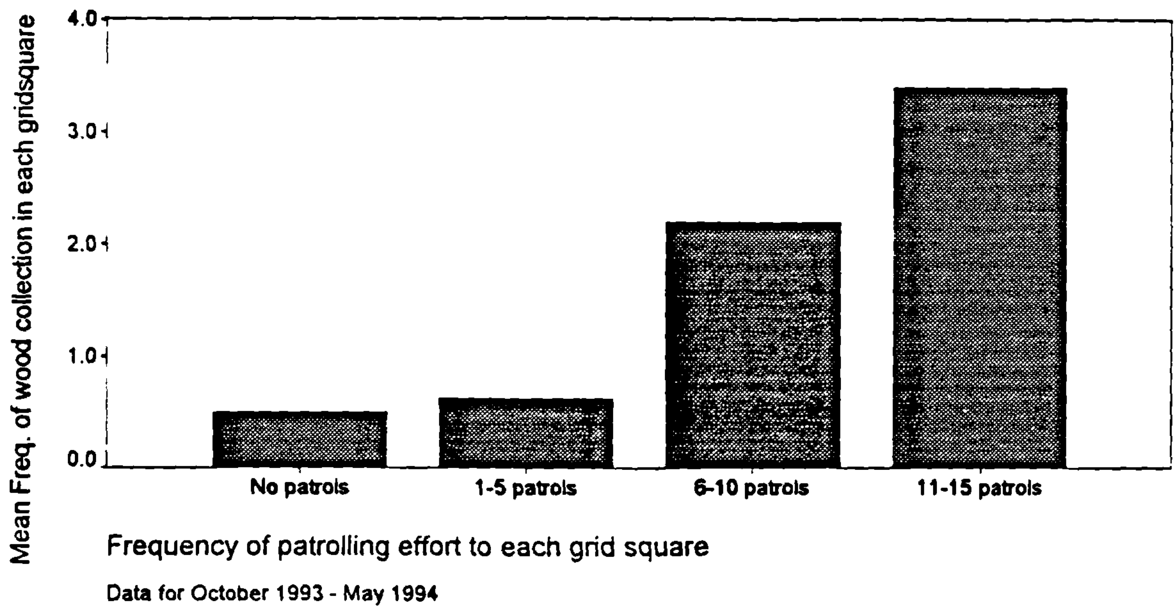


Figure 9. Comparison of the grid square destination of wood collection groups and scout patrols.

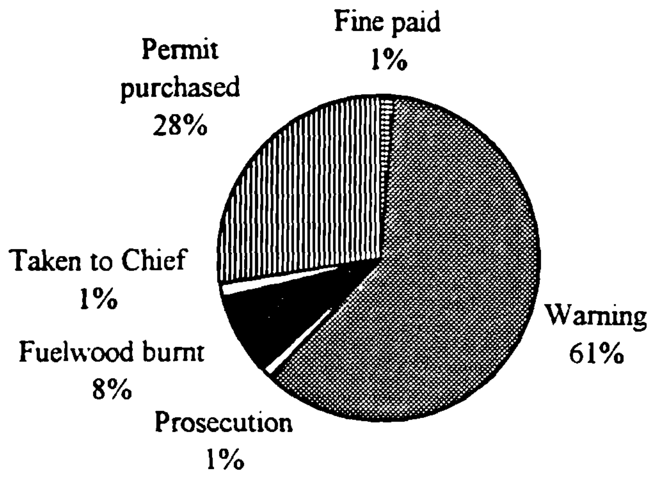


Figure 10. Penalties imposed by Park scouts to illegal wood collectors.
Number of encounters = 76 (October 1993 - May 1994).

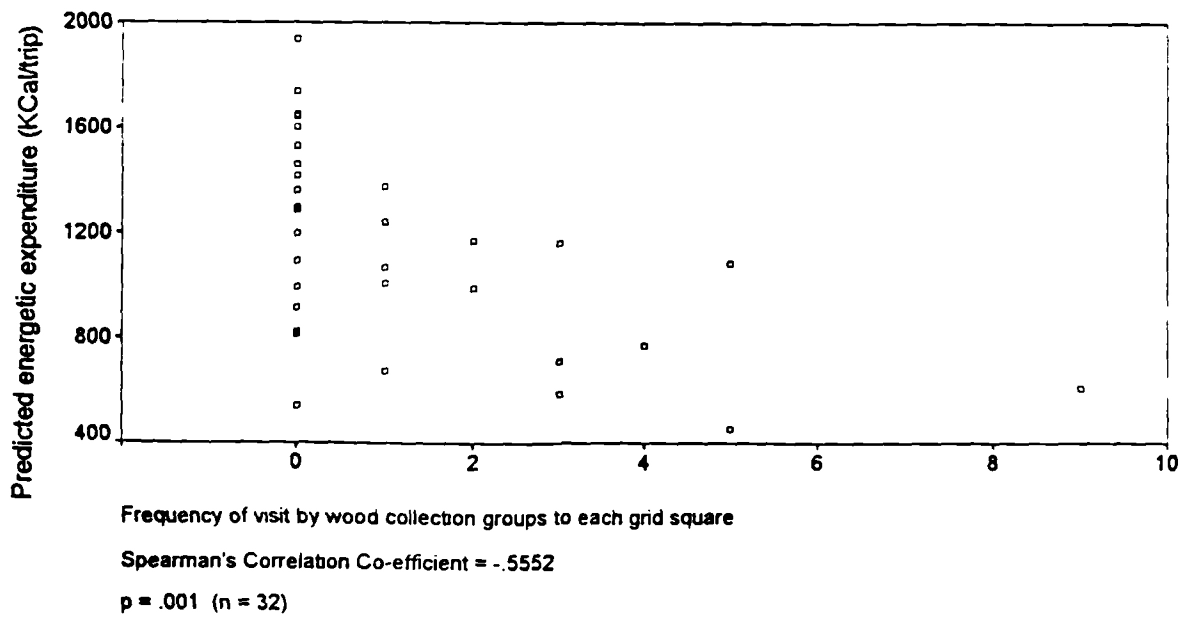


Figure 11. Correlation of the energetic cost of visiting each grid square and patrolling effort.

Figures 12 and 13 compare the availability of habitats within LMNP with those selected by groups of wood collectors. Wood collectors show a strong selection for mixed woodland. The energetic and time costs for wood collection in each of the three habitats are shown in Figure 14.

Figure 12. Habitat availability within Lake Malawi National Park.

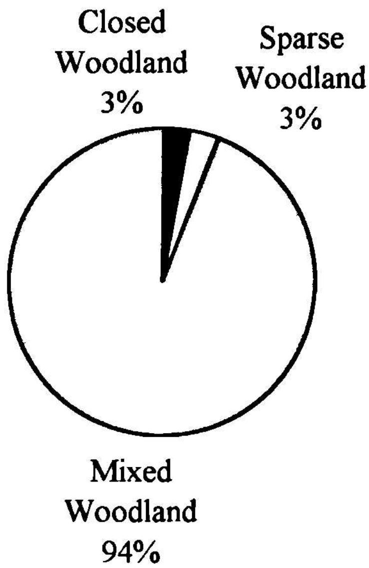


Figure 13. Habitat selection by wood collection groups.

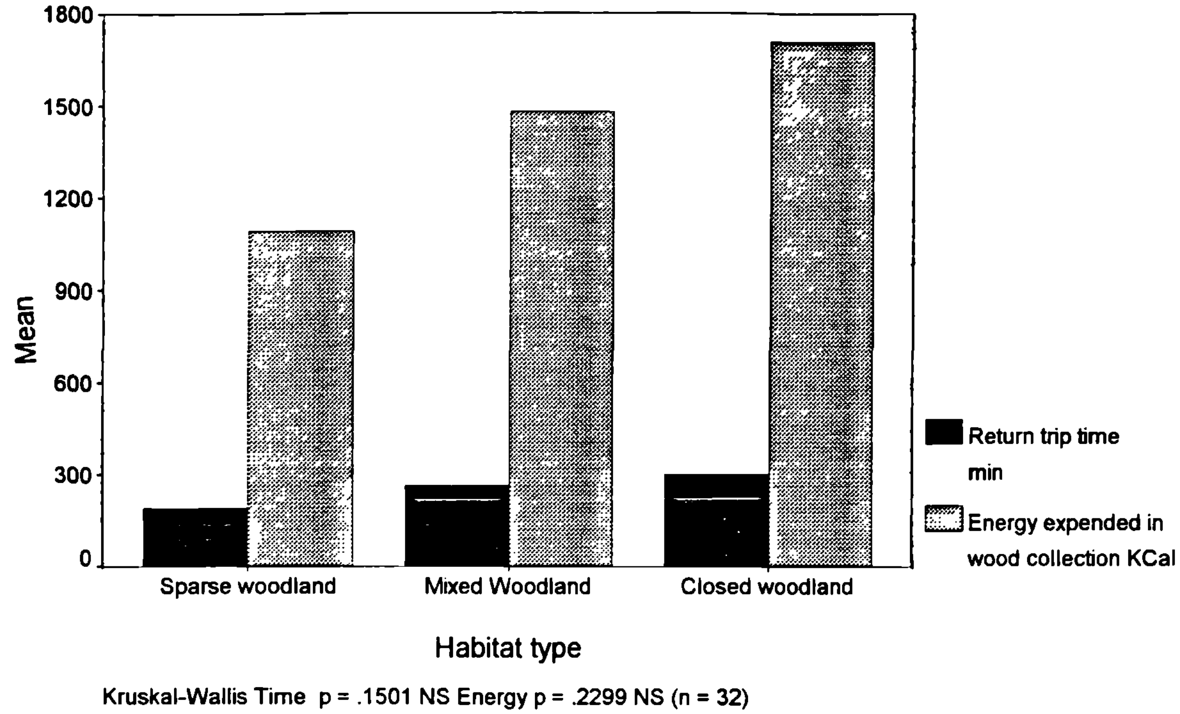


Figure 14. Time and energetic costs for wood collection in different habitat types.

Discussion

Prediction 1: Time minimising

Wood collection groups appear to concentrate foraging effort in the more accessible areas of the Park. Figure 1 shows a strong tendency for wood collection in grid squares with a low time cost. This result suggests that time may be a consideration in female foraging decisions. Figure 2 shows that the rate of wood collection is reduced at increased journey length. Women living both near and far from the resource base make journeys of a range of different lengths, with the shortest journeys available to women who live close to the woodland (see below). To minimise their time costs and maximise their rate of wood collection, the graph suggests that women should make shorter journeys. However, groups fail to concentrate foraging effort at short journey times that would maximise their rate of wood collection.

Prediction 2: Energy Minimising

Similar to the patterns of resource use with regard to time, Figure 3 shows that wood collection groups show a strong tendency to visit grid squares that require a low energetic expenditure per trip. This implies that energetic costs of wood collection are a consideration for women. Figure 4 compares the energy efficiency of wood collection (the amount of wood collected per unit of energy expended) with journey length. This shows that energy efficiency is maximised for short journeys. Yet groups of women, who live both near and far from the resource base, make long journeys which reduce their energetic efficiency. This graph is similar to Figure 2, which shows that the rate of wood collection declines with distance from the village.

Time and Energy

The time and energy costs of wood collection are similar. This is highlighted in Figure 5, which partitions the data set into grid squares according to their level of use for wood collection. Grid squares that were never visited command significantly higher energy and time costs for wood collection than squares visited more frequently. Although wood collectors appear concerned with minimising energy and time costs, they fail to maximise either their rate of wood collection or energetic efficiency. This would require women to make short journeys and collect wood close to the village. However, the results show women make a range of journeys but fail to concentrate foraging effort in the more accessible areas of the woodland, with shorter journey times.

These results seem counter-intuitive. Women select areas of the woodland to minimise the time and energetic costs in fuelwood collection. However, the corollary of these predictions, that women should try to maximise their rate of wood collection and energetic efficiency, they fail to achieve. These results may be explained by examining the mean load size gathered by wood collection groups.

Figure 6 contrasts the wood collection activities of women that live both near and far from the woodland. As outlined previously, central place foraging theory predicts that optimal load size should increase with distance travelled to the resource base. However, the results show that the equivalent sized loads were gathered by groups of women, regardless of their proximity to the resource base. This was investigated further by analysing the variation in mean load size with journey length for the forty-two groups of women (Figure 7). It shows that journeys of varying length are made by women living both near and far from the woodland. However, very little of the variability in load size is determined by journey time. Clearly, load size is not significantly increased in response to increased journey time.

One interpretation of these results is that the optimum load size is always much larger than can be headloaded. Thus women gather the maximum wood they can carry, regardless of the journey they have made. This is consistent with a model of linear gain function, where individuals do not experience resource depletion within the patch (see Krebs and Davies 1991). This may be an appropriate model because although fuelwood collectors are essentially central place foragers, a multiple-prey loading model is inappropriate because women are not constrained by the resources they have already collected. A description of fuelwood collection practices will help to demonstrate this point.

Searching for fuelwood in the woodland in large groups (mean size 5.71, range 2 - 17), women adopt several strategies. Arriving at an area where they agree to collect (the fixed point), the women radiate out to collect fuelwood. Some women return several times to the fixed point with small loads of wood until they have collected sufficient to make their bundles. Others search away from the fixed point in a line, gathering branches into piles which they tie into a loose bundle and headload to the fixed point. It is at this central location that the women, as a group, tie their bundles and rest before returning to the village. Hence women are constrained by the wood they have gathered only while it is held in their arms. When they return to the fixed point, they are able to join the wood together into a large bundle which they headload back to the village. They therefore avoid the problems of loading encountered by less dexterous species (such as chipmunks, Giraldeau and Kramer 1982).

Furthermore, as groups of women return to the same areas of woodland on successive trips, resource depletion in an area is seen to occur over a long time period and may not be experienced within a foraging trip. Thus, these foragers are unlikely to experience the diminishing returns predicted by the marginal value theorem from either resource depletion or from the increasing load size.

As there is no significant wood gain for making longer journeys, wood collectors maximise both their rate of wood collection and energetic efficiency when they make shorter journeys. Yet the results show that many groups make long journeys which reduce their efficiency of wood collection. One explanation of this may be the availability of fuelwood. It is postulated that as distance from the village increases, the woodland is less disturbed and it is easier to collect a bundle of wood. This is consistent with the models of concentric circles of deforestation around population centres (Whitney 1987). Furthermore, the availability of dead wood in Zimbabwean *miombo* has been shown to increase with increasing distance from the village (Grundy et al. 1993).

Therefore, wood collectors may have the option of accessing woodland close to the village where it is difficult to secure a bundle of wood (time cost in collection), or, walking to more remote areas of the woodland where fuelwood gathering is easier (time cost in travel). This trade-off is examined in Figure 8, which contrasts patch time with journey length. While patch time is highly variable, it is clear that by travelling further women are not able to reduce their within-patch time costs. The lack of a trade-off between journey length and patch time is somewhat surprising. However, patch time includes other activities, such as resting and socialising. Longer travel times may require women to rest more within the patch. However, it is clear that by travelling further, women are not minimising the time they allocate to wood collection.

To reiterate, the results suggest that women collect wood in areas that require low time and energy costs per trip. Because there is no significant wood gain for extra distance travelled, women should opt for the shortest journey times to maximise their energetic efficiency or rate of wood collection. However, wood collectors make journeys of varying length but fail to concentrate foraging effort close to the village. Longer journey times are not compensated for by shorter patch times.

Prediction 3: Risk Minimising

It is possible that women travel further than appears necessary for energy or time efficient wood collection because they try to avoid law enforcement patrols. This is examined in Figure 9, which contrasts the destination of wood collection groups with scout patrols. Contrary to expectation, the graph shows that rather than selecting low-risk areas, wood collection groups frequent grid squares with the highest patrolling effort. Such risk-prone behaviour seems counter-intuitive given that most women collect illegally and are subject to various penalties if caught.

One interpretation of these results is that the scout patrols are efficient in targeting areas that are used most frequently for wood collection. However, even the most frequently patrolled grid square was visited only fifteen times during the eight month study period i.e. < 2 patrols per month. Given that women collect fuelwood about every four days (see Chapter 8), it seems that the risk of detection when collecting wood illegally is extremely low, even in the 'high risk' areas.

The penalties imposed by the Park scouts for illegal wood collection are shown in Figure 10. This shows that most illegal wood collectors received a warning. More severe penalties were issued much less frequently. This may reflect the Park's recent policy shift towards more lenient penalties for illegal wood collectors to improve community relations. The requirement to purchase a permit for fuelwood collection had been a major point of contention between the MDNPW and the enclave villagers (see Grenfell 1993).

However, these data suggest that neither the risk of being caught nor the penalty imposed for illegal wood collection are likely to affect women's foraging decisions if maintained at their current levels. While women claim to be unable to afford a permit (see Chapter 2), these results suggest that it is not in their interest to do so and may explain why so many women collect wood illegally. Women are unlikely to encounter scout patrols even in the highest risk areas or receive a penalty which would be a sufficient deterrent. Of the factors that reduce the incentive for illegal activity, research suggests that the detection rate is more of a deterrent than the penalty level (see Leader-Williams and Milner-Gulland 1993). These results suggest that the detection rate is too low for patterns of wood collection to be influenced by law enforcement activities.

Furthermore, Figure 11 shows a significant negative correlation between energy costs in accessing grid squares and the level of patrolling effort. This suggests that scout patrols appear to minimise their energetic expenditure while on patrol. This may explain why women and patrol groups tend to visit the same areas of the woodland (see Figures 3 and 9). While wood collectors and scout patrols appear to target areas which minimise their energetic expenditure, this does not pose a risk to the women as patrolling effort is too low to influence their foraging decisions.

Prediction 4: Selection of High Quality Habitats within the Woodland

As law enforcement appears not to affect female foraging decisions, habitat (as a proxy measure of wood quality) is used to try and explain why women make long journeys when this reduces their energetic efficiency and rate of wood collection. It is postulated that by travelling further, women may improve the quality of their bundles, ensuring they contain a range of suitably sized species. Collecting close to the village may reduce travel and energy costs and maximise efficiency but the bundles may contain smaller sized wood and fewer hard wood species. The latter burn more slowly and are more energy efficient. By travelling further to collect high quality fuelwood, women may actually reduce long term foraging effort since supplies may last longer, requiring fewer collection trips.

Figures 12 and 13 compare habitat availability within LMNP with those selected by wood collection groups. Those grid squares visited most frequently contain mixed woodland. This habitat is selected more frequently than would be expected from its availability within the environment. Collecting in sparse or closed canopy woodland is very rare. Women select closed canopy woodland much less than would be expected from its availability, yet this is the habitat which contains the preferred hard wood species which define *miombo*.

That women actively avoid closed canopy woodland may be partially explained by Figure 14. This plots the trends in mean time and energy costs in collecting in each of the three habitat types. Sparse woodland has the lowest energetic and time costs, being positioned at the base of slopes and accessible to villagers. However, women collecting in this habitat would be unlikely to find fire-sensitive hardwood species, such as *Brachystegia microphylla*, which are preferred fuelwoods (see Chapter 6). By contrast, there are high time and energy costs in accessing closed canopy woodland which does contain the preferred hard woods. This is because *miombo* is positioned at high altitude, on upper slopes, away from the disturbance from the villagers (see Chapter 5). The habitat selected by most wood collection groups, mixed woodland, has intermediate energy and time costs in its utilisation.

It is hypothesised that in mixed woodland, women may be able to maximise their energetic efficiency and rate of wood collection within the constraint of wood quality, collecting wood from a range of species and size classes. It should be noted that the differences in time and energy costs in accessing the different habitats are not significant. This may be because habitat is a crude measure of wood quality and preference. There is also great variation in the costs in accessing grid squares within each of the habitat types. These data are analysed at the level of the grid square ($1km^2$) and women may be collecting wood from anywhere within that area. For mixed woodland, it is not known whether women are selecting the sparse or more closed canopy areas for wood collection. Their movements within that square will determine their time and energy costs as well as the quality of the wood collected.

Without data on the composition of bundles collected by women foraging at different distances from the village, it is difficult to investigate further the effects of wood preference on foraging decisions. However, as women are actively selecting areas within the woodland and show distinct preferences for certain fuelwood types (see Chapter 4), it is not unreasonable to assume that this would strongly influence their foraging decisions.

A final test of habitat selection would be to compare the time and energy costs, rate of wood collection and energetic efficiency of wood collection in each of the three habitats for the groups that were tracked. However, of the thirty-two groups for whom there is a complete data set, thirty collected in the mixed woodland, one in the scrub and one in the closed canopy. I cannot therefore test these factors and habitat can only be investigated in terms of predicted time and energy costs of wood collection in each of the habitat types.

Conclusions

This chapter has investigated the wood collection activities of groups of women from Chembe village. Taking a cost-benefit approach, the effects of time, energy, law enforcement and habitat selection were examined for their influence on female foraging decisions. The results suggest that wood collection groups select areas within the National Park which minimise their expenditure of time and energy. This study attempted to explain the variation in the length of journeys made by groups of wood collectors. Longer distances are not compensated for either by reduced patch times or enhanced load sizes. Thus wood collectors who make longer journeys have reduced rates of wood collection and energetic efficiencies. Law enforcement activities cannot explain why women make these long journeys: the risk of detection is too low, and the penalties imposed by the Park scouts too light, to affect women's foraging decisions. Habitat selection seems to be an important factor. Women actively select areas of mixed woodland and avoid closed canopy woodland for fuelwood collection. The energetic and time costs of accessing each habitat are thought to influence habitat preferences. Thus women's wood collection appears to minimise the energetic and time expenditure per trip within the constraint that wood must be of a certain type and quality. This requires selection of appropriate areas of woodland around the village.

These findings have implications for the community participation *versus* preservationist debate in approaches to conservation (IIED 1994). They lend little support to a law enforcement approach to conserving LMNP woodlands. At the current levels, scout patrols do not appear to affect patterns of wood collection yet are a point of major contention between villagers and LMNP authorities. An option for the MDNPW is to increase the patrolling effort in LMNP but law enforcement activities fail to address the problem that the Park woodlands are the only source of fuelwood for enclave villagers. Thus, a more proactive role for scouts in providing alternative sources of fuelwood (e.g. tree planting and establishing tree nurseries) may have a more beneficial impact on the woodlands than imposing penalties on wood collectors for illegal collection of a primary resource.

Furthermore, the analysis presented in Chapter 6 suggests that the wood collected for fish smoking has a more damaging impact on the Park woodlands than domestic fuelwood collection. Over 90 per cent of scout encounters with wood collectors were with women. This suggests that the patrolling system fails to address the more damaging form of wood use. Better targeting of scout patrols to detect the illegal felling of hardwood canopy trees may have a more direct impact on woodland conservation than penalising domestic wood collectors.

Chapter 10

Concluding Discussion

This chapter is divided into three sections which review the thesis approaches, findings and application in the context of the current literature. The first section provides a detailed rationale of the methodologies used to study rural subsistence practices. The second section integrates the specific findings of the research in the context of the analytical and theoretical background to studies of resource use. In the final section, the application of this research is discussed together with the implications of this study for future research and the management of LMNP.

Approaches and Methods

There has been much debate about the role of development research. Stemming from failure of many aid initiatives, it has been argued that better focused research would assist development planners to allocate resources more efficiently. In particular, there has been increasing recognition of the need to address the complexity of the whole system under study rather than any single component in isolation. This has required an horizontal approach to research and the development of multi-disciplinary methodologies, particularly in the study of natural resources. These approaches have been paralleled by an increased awareness of indigenous knowledge systems and the use of participatory research techniques to enable local people to analyse their own experiences. The history and rationale of the changing theoretical and practical approaches to the study of human ecology and development have been introduced previously in Chapter 1.

Over the last twenty years, numerous studies have addressed energy supplies and forest resources in the developing world (see reviews by Eckholm et al. 1984, Leach and Mearns 1988, Soussan et al. 1992). Within the changing theoretical framework and building on the findings and learning from the inadequacies of earlier research, new approaches have been developed that take a broad approach to defining rural energy. More recent studies encompass a range of forest products and indigenous resource management, of which fuelwood is just one component. The more integrated approach assesses the role of forest resources in subsistence practices and for food security and income generation.

However, methods and approaches are tools for exploration. Their efficacy in defining local patterns of resource use depends on the quality of execution. New approaches challenge the 'survey slavery' of conventional social science research (see Chambers 1983) but an uncritical application of the newer, participatory techniques can also be questioned. By its nature, rapid rural appraisal (RRA) is necessarily constrained to the same problems of earlier approaches i.e. undertaken in accessible communities, biased to the season of study, focused at those people who are willing to participate etc. (see Chambers 1983). Moreover, through its rapidity, RRA necessarily overlooks questions of representative data, village divisions and awareness of the personal agendas of individual informants. The abuse of RRA undermines participatory approaches by 'legitimising' consultation with a fixed minority, the key informants, within the village. Because the precision of the data produced by participatory tools appears to depend on who is consulted and who is facilitating, such studies may lack replicability. Thus, it may be argued that despite its inadequacies, a questionnaire survey approach may be preferable to the uncritical use of participatory techniques because the defined sample size secures representation of a greater number of people (albeit with limited flexibility for consultation on the issues under study).

The development of participatory research, in particular participatory rural appraisal (PRA) and more recently, participatory learning and action (PLA) have helped to overcome some of the criticisms levelled at rural appraisal techniques. Recent typologies of participation (see Pimbert and Pretty 1995) enable participatory approaches to be appraised and should lead to their more informed application. Notwithstanding the problems associated with their uncritical application, participatory tools provide an informal setting for researchers to introduce themselves to villages. Moreover, through the use of media appropriate to the setting, they have the potential to empower certain sectors of the community with the confidence to share their analyses of their environment.

The time required to gain a sufficient understanding of the system, particularly to represent the views of more hidden groups (e.g. the poor and women), is an important element in both formal and participatory research. Yet time must be balanced against other resources. The lengthy techniques associated with the early farming systems approach which aimed to address 'the subsistence economy' have in practice been refined because neither time nor resources (nor researcher and subject fatigue) enable all aspects of a system to be studied (see Bradley 1991). Hence, 'holistic' research tends to cover three main areas, which have also been the main focus of this study:

- time allocation in subsistence strategies (derived from social sciences, particularly anthropology)
- resource base and impacts (derived from natural sciences)
- economic analyses (derived from social sciences)

A variety of methods ~~were~~ was used in this study to ensure measures of resource use at the level of the household, market and resource base. This enables an assessment of the contribution forest products make to subsistence and income generation and the effects of utilisation on the woodland resource. The combination of methods and formal and participatory approaches provides a balance between the need for scientific rigour while addressing locally appropriate real, rather than imported, issues. This is a difficult and challenging approach for a PhD thesis and the Acknowledgements section indicates the wide range of people and organisations that were consulted to enable the most appropriate methodologies and analyses to be drawn.

PRA was used in project planning and repeated throughout the study to explore specific issues raised from the more formal survey methods. Formal methodologies were required to gain an increased, quantitative understanding of patterns of resource use. The inherent lack of precision in PRA stems from its reliance on peoples' own analysis and recall, which is necessarily shaped by their own experience. Appropriate application of formal research methods enables testing of the extent to which recall and description provide a satisfactory construction of the system under study. Quantitative data on patterns of resource use and their ecological impacts enable a rigorous analysis of the opportunities for, and constraints of, utilisation, conservation and exploitation of natural resources.

In recent years, an increasing number of quantitative socio-ecological studies of resource use have been undertaken using approaches and methods adapted from behavioural ecology (e.g. Hawkes et al. 1982, Alvard 1993). Through progressive testing of explicit hypotheses generated from evolutionary theory we have an improved understanding of some of the factors and behaviours that determine patterns of resource use (see Alvard 1995). Such approaches enable temporal and cross-cultural comparative analyses of patterns of resource collection and use (e.g. Blurton Jones et al. 1989, Hurtado et al. 1992). Frequently, human behavioural ecology has been applied to hunting behaviour and use of wild animal resources (e.g. Hill 1988, Hawkes 1990, Alvard 1993, 1995,). Part of the present study has adopted similar approaches to examine the use of plant resources, particularly to identify factors that affect fuelwood collection within a protected area system.

Research Findings

This section reviews the main findings of the data generated from multi-disciplinary approaches to studying patterns of resource use within LMNP. The first section gives a short, general description of community use of non-timber forest products (NTFPs) harvested from the *miombo* woodlands of the protected area. This is followed by an analysis of the potential for widening the location of sale for NTFPs that are currently traded locally. This is consistent with current thinking in conservation for the economic benefits of a protected area to accrue to the local population (IIED 1994). Subsequently, a more detailed exploration of patterns of natural resource utilisation by the resident communities and its impact on the *miombo* woodlands of LMNP is presented. The final sections focus on the collection and use of domestic fuelwood. Patterns of domestic fuelwood collection by women and their daughters are described in the context of theories of fertility and the contribution that children can make to the household economy in developing countries. This section also explores the effects of family size on patterns of fuelwood consumption. Finally, some of the factors that affect the decision-making in domestic wood collection within a protected area are explored using a cost-benefit analysis. The application of these findings for the integrated management of LMNP are outlined in Appendix 14.

Non-timber Forest Products (NTFPs)

In common with the findings of recent resource use studies (e.g. Koppell 1990), PRA in the enclave villages revealed that a diverse range of forest products are collected from the Park woodlands. This harvesting continues despite the fact that collection of natural resources from the protected area is illegal (with the exception of deadwood with a permit). The PRA indicated different harvesting and use practices for natural resources, according to age and gender, which provided a focus for further study (see below). For the purposes of this study, NTFPs have been classified into primary and secondary products. Primary products are used regularly by each household and include fuelwood, building poles and grass thatch. These products have been the major focus of this thesis, which builds on the PRA findings to examine in more detail NTFP collection and use practices and the impact of harvesting on the woodland resource base. Secondary products include a range of resources that are used more sporadically or by only certain sectors of the community. These products were studied in the context of the potential for urban trade in those natural resources that are currently marketed locally.

Marketing Strategies for NTFPs

In recent years extractive reserves have been advocated as a method of conserving biodiversity while directing the economic benefits of natural resource harvesting and marketing to local people. Numerous recent studies value forests on the basis of their production of NTFPs (e.g. Peters et al. 1989). Developing methodologies for valuing NTFPs, Godoy et al. (1993) value NTFPs using forest gate prices, the point at which villagers first sell or consume their goods. By contrast, the present study used simple analyses of the interspatial price margin, transport costs and the opportunity cost of labour to explore the feasibility of developing marketing strategies based on widening the point of sale for NTFPs. While some NTFPs from LMNP are currently traded, PRA revealed that most products are sold locally within the enclave villages. By combining participatory and formal research methods, this study explored the potential for increasing the profitability of trade in NTFPs by changing the location of sale from local to urban markets. The analysis included primary products and key secondary products (particularly wild fruits and insects) that are currently traded within the villages. The profitability of urban fish trading, the main subsistence activity in the villages, was contrasted with the marketing of NTFPs to compare the marketing potential for woodland *versus* fish products.

This analysis identified three basic constraints to the urban marketing of woodland resources from LMNP: the availability of the product, the low economic value of the product and the high cost of transport to alternative markets. The product that showed the greatest potential for trade was flying termites. The high urban profit margin for this NTFP reflects urban demand for a product with localised availability, being confined to the termitaria within *miombo* woodland. Notwithstanding, the supply constraints with this resource, the present analysis indicates that the price of a product and the potential for profitable spatial arbitrage are related to availability, as predicted from basic 'supply and demand' economic theory. Thus, NTFPs which show the greatest potential for trade occupy niche markets i.e. they have a limited productive supply (temporally or spatially) and high demand, at a regional or national level. The high urban profit margin for fish reflects this marketing pattern, fish has a national demand but a limited distributive supply. Furthermore, the fish trade is profitable because it depends on the free extraction of natural resources from Lake Malawi and LMNP woodlands (see below).

The isolation of rural communities, particularly those residing within or adjacent to protected areas, appears to preclude the development of wider marketing strategies. In particular, the urban profit margin is insufficient to offset the high cost of transport, regardless of the quantities of NTFPs transported. Poor communications were also identified as an obstacle for local people in marketing high volume, low value forest products in the case of communities living in and around Korup National Park, Cameroon (Amadi 1993). While a farm-to-market road is being constructed in Cameroon to facilitate trade, recent studies highlight the ecological and economic impact of and obstacles faced by marketing NTFPs (see May 1991, Hanson 1992, Hall and Bawa 1993). Homma (1992) suggests that NTFP harvesting is an important economic activity in the short term but does not provide a satisfactory model of either ecologically or economically sustainable forest utilisation. The present study supports the findings of Salafsky et al. (1993) that while extractive reserves provide economic, ecological and social justifications for conservation, their viability depends on prevailing local conditions. Thus, while urban trade in NTFPs appears unprofitable for most products, local sale of products is likely to remain an important economic activity for poorer households in the village. Local use of NTFPs for household subsistence and income generation, together with the environmental services provided by the *miombo* woodlands, appear to provide a more judicious rationale for conservation in LMNP than an extractive reserve.

Impacts of Community Utilisation of* Miombo *woodland

This section reviews the different approaches used to assess human impacts on the Park woodlands. The results from the vegetation survey and aerial photographic analysis provide direct measures of the status of the resource base. These data are integrated with formal village surveys which provide quantitative data on patterns of woodland utilisation and an indirect or inferred measure of the impact of harvesting on the resource base. In combination, the three measures of *miombo* woodland utilisation: a vegetation survey, aerial photographic analysis and village surveys of patterns of resource use (including household surveys, fishsmoking surveys, focal group follows of fuelwood collectors) suggest that human communities in LMNP have a substantial impact on the woodland resource base.

- **Fire, Grass Thatch and the Ecological Dynamics of miombo**

Fire is a feature of the *miombo* woodlands of Africa (see Trapnell 1959). Although shifting cultivation is not undertaken in LMNP, there are many fires in the woodlands throughout the dry season. The cause of these fires has been difficult to establish, being attributed variously to villagers and scouts from the Malawi Department of National Parks and Wildlife (MDNPW). Some woodland fires appear to be accidental in that fires used to clear farm plots may spread to the protected area. Conversely, villagers living close to the woodland may deliberately burn the woodland early in the dry season to prevent an accidental woodland fire spreading to the village. Thus, fires may occur both late and early in the season. But it is late fires that are especially damaging to the regeneration of *miombo* hardwoods which are the preferred fuelwood species (Lawton 1978, see below). However, while early fires help to maintain *miombo* species and prevent a serious late fire, they destroy the grass layer and prevent a harvest of thatch. This primary resource is an important local construction material, used for roofing houses and building fences (see also Cunningham 1993).

Thus, there is potential for village conflict in the timing of woodland fires, depending on a household's proximity to the woodland and their thatch requirements. Further conflict arises because villagers blame MDNPW scouts for the early fires which prevent the harvesting of grass thatch and the scouts blame the villagers for late season fires. Whatever their cause, observations during my eighteen months residence at LMNP suggest that fires are a frequent occurrence in Park woodlands during the dry season. This is corroborated by the vegetation survey which suggests that fire has a profound influence on the woodlands.

Studies of the ecological dynamics of *miombo* suggest that fire is a key determinant of floristic composition and directs succession between *chipya* and *miombo* communities. Protracted burning experiments in Zambia (see Trapnell 1959, Lawton 1978) indicate that burning early in the dry season maintains regeneration of *miombo* dominants (e.g. *Brachystegia*) and mitigates against the effects of a serious, accidental fire. Burning later in the dry season impedes the regeneration of fire sensitive species and promotes the regeneration of fire tolerant and shade intolerant *chipya* species. Under natural conditions, woodland sites are likely to be subjected to either an early or late fire in most seasons, although in some years there may be a complete absence of fires (see Lawton 1978). Under the 'natural burning' regime a dynamic continuum of species from *miombo* and *chipya* ecological groups is maintained. However, consistent late burning reduces the representation of fire sensitive *miombo* species in the canopy. These are superseded by *chipya* species which provide a reduced canopy cover. Thus, late burning inhibits the regeneration of *miombo* dominants which are preferred local species of fuelwood.

The vegetation survey revealed the species composition of the LMNP woodlands which may be interpreted in the context of the dynamic ecology of *miombo*. Exploratory data analyses (see Kent and Coker 1992) were employed to relate measured environmental variables to the observed floristic composition of the Park woodlands. These provide an assessment of the extent to which various ecological factors account for the observed variation in species assemblages. Ordination and the related Monte Carlo permutation tests were employed to test the statistical significance of measured environmental parameters. Thus, while a single vegetation survey provides a static portrait of floristic composition, multivariate and exploratory data analyses that link species distribution to measured environmental variables, enable a tentative reconstruction of recent land-use practices.

The analyses suggest that all the measured physical factors (e.g. altitude, position of the quadrat on the slope, accessibility) have a statistically significant influence on the floristic composition of the *miombo* woodlands. However, the specific distribution of *chipya* and *miombo* species suggests a response to influences other than physical position. It is postulated that anthropogenic disturbance is a key determinant of floristic composition. Thus, vegetation appears a response to a complex gradient of physical upon which other factors (e.g. anthropogenic fire and cultivation) are acting. Accessibility and position of the quadrat on the slope appear as independently important environmental gradients which together represent some index of the potential for disturbance. Fire appears to be an important agent of disturbance in this context. Given the small size of LMNP and the large human population, fires are likely to be of anthropogenic origin, whether deliberate or accidental. This interpretation suggests that measured physical variables determine the frequency and timing of fires, which in turn influences species assemblages at a given woodland site. Thus, proximity to human settlement is an important parameter that determines the level of disturbance that acts upon a site and, ultimately, its floristic composition.

The present study suggests that sites proximate to villages show disturbed *chipya*-type vegetation while *miombo* species tend to occur at sites at greater distance from village settlements. Thus the fire sensitive , succulent and evergreen species that comprise *miombo* occur in less disturbed areas, such as at relatively inaccessible, higher altitude sites. The protected island site displays a range of fire sensitive *miombo* species that are found either exclusively on the island or have a more limited distribution in the rest of the Park. The absence of *chipya* species on the island is particularly conspicuous and is attributed to the low incidence of fire at this isolated site.

Chipya species predominate in the most accessible sites, proximate to villages, which have a high risk of fire (see also Bootsma 1987). *Chipya* communities reflect consistent exposure to late fires (Trapnell 1959). The highly disturbed site proximate to Monkey Bay which had been farmed in the past and burned more recently, had a very low tree density, with no understorey. This site appears consistent with Werger and Coetzee's (1978) observations that *miombo* sites with a history of late burning become virtually devoid of trees. The occurrence of *chipya* communities in over half the quadrats indicates widespread disturbance through out LMNP. This reflects in part cultivation plots abandoned since the Park was established in 1980, but more extensively, sites subjected to continual late fires.

Although Trapnell (1959) predicted that *miombo* may be destroyed by late burning, it appears that the coppicing ability of many species, including *miombo* species, may be an adaptation to disturbance that confers a degree of resilience on natural systems (Nyerges 1989). This suggests that *miombo* species may be recovered in LMNP through implementation of an appropriate burning regime designed to maintain a continuum of *miombo* and *chipya* communities. The vegetation analyses demonstrate the need for spatially and temporally defined fires to maintain *miombo* species, particularly the canopy dominants (e.g. *Brachystegia microphylla*), within LMNP. Such a controlled burning regime uses fire as a tool for determining floristic composition and maximises biological diversity through conserving a continuum of *miombo* and *chipya* communities.

- **Temporal Woodland Change and the Harvesting of Woody Primary Products**

The results from the aerial photographic analysis suggest a low level of sparse woodland in 1982. The analysis suggests a recent change in woodland cover with a 299 per cent net increase in sparse woodland between 1982 and 1990, predominantly in areas that appear previously to have been occupied by closed canopy woodland. In the absence of large mammals and livestock in LMNP, the increase in sparse woodland is attributed to human utilisation of the woodlands. The population of the five enclave villages comprises 8440 people (1994 census) who are enclosed by a national park with an area of just over 90 square kilometres. The villages have a high level of dependence on the woodland for woody primary products, such as construction materials and fuelwood. The analysis suggests that over the time period studied there has been an increase in the distribution of sparse woodland away from the village centres. One interpretation of this finding is that as areas of woodland proximate to the villages are depleted, villagers travel further to exploit the woodland resource base.

There are three main uses of woody products within the villages: domestic fuelwood, fuelwood for fish smoking and construction materials (e.g. building and roofing poles). The collection of wood for each of these purposes is likely to impact upon the Park woodlands given the large quantities of wood required. However, examination of the different wood selection and collection practices suggests that not all harvesting practices have an equal impact on the resource base (cf. Hall and Rogers 1986).

Patterns of domestic fuelwood collection suggest that women may not be the only, or major, cause of the observed decline in woodland cover between 1982 and 1990. Women tend to lack the tools required to fell trees and this is reflected in the small size of the wood collected (mean mid-point diameter of domestic fuelwood is 3.6 cm), a convenient size to cut, carry (headload) and use within the household. Species selection for domestic fuelwood is broad, encompassing nearly one third of the species recorded in the vegetation survey. Furthermore, the estimated production of deadwood suggests that there is sufficient quantity of this preferred resource to meet the domestic fuelwood requirements of all five enclave villages. However, in areas where deadwood is exhausted or of insufficient quality, small sized live wood may be cut for fuelwood.

While large numbers of poles are used in house construction, these items have extended durability and, like domestic fuelwood, are selected from a wide species base. There is a limited literature only that documents the effects of cutting poles on woodland structure and regeneration (see Hall and Rogers 1986). But it indicates the important role of vegetative reproduction, through coppicing from the stumps and root masses of felled trees, in promoting woodland regeneration (Stromgaard 1986b, Nyerges 1989). Recent studies suggest that coppicing facilitates woodland recovery, increases productivity and thus offsets local harvesting pressures (Shackleton 1993, see Chidumayo 1993 and Grundy 1993 for studies in *miombo*). On the basis of the current literature, it appears that while pole collecting may have long term effects on woodland diversity and structure, the cutting of understorey trees for poles is unlikely to have caused the marked reduction in closed canopy woodland.

The third major use of wood in the villages is that used for fishsmoking. Unlike wood used domestically, species selection for this activity is narrow. Just fifteen different species were recorded during the eleven month monitoring period. Nearly two-thirds of the observed wood was *Brachystegia microphylla* which is the dominant, hardwood canopy tree. Furthermore, wood of a large size class was selected: on average, the wood used in fishsmoking has a midpoint diameter six times larger than domestic fuelwood. Wood for fishsmoking is collected by men who have both the tools (e.g.

axes and saws) and transport (e.g. boats, bicycles and canoes) required to cut and carry such large loads. The large size and few species of wood selected suggests that fishsmoking would have a direct effect on canopy cover. The selection of canopy dominants leaves a gap in and opens up the woodland canopy (cf. Medley 1993). This light environment favours regeneration of shade intolerant *chipya* species rather than *miombo* species. Thus, the harvesting of fuelwood for fishsmoking (together with the *ad hoc* burning regime) appears to promote the regeneration of *chipya* rather than *miombo* species and account for the recent decline (see below) in closed canopy woodland within LMNP.

The present study indicates that gender differences in resource collection affect the impact of harvesting practices on the resource base. Of particular relevance are gender differences in the access to tools for resource harvesting and modes of transportation. These appear to be important factors that play a role in determining wood selection and cutting and thus the impact that harvesting has upon the resource base.

- **Population change and the artisanal fishery**

The recent change in woodland canopy appears to be concurrent with the increase in demand for fish smoking associated with population migration to the southern end of Lake Malawi during the 1970s (Kapeleta 1980, McCracken 1987). The historical pattern of settlement of LMNP suggests that fishermen from the Malawi's Northern region expanded the use of gill nets, and consequently fishsmoking, on the Nankumba Peninsula. The improved fishing technologies introduced by the Tonga and Tumbuka fishermen initiated a change from subsistence to commercial fisheries within the villages of LMNP.

During PRA sessions, the villagers would often assert that the migrant communities ('the Northerners') were destroying the woodland. They believe that the Northern ethnic groups have only short term interests in the Park's natural resources because they will eventually return to their home region. Fairhead and Leach (1995a) suggest that it is often convenient to blame migrant communities for irresponsible resource use and environmental damage. However, this study suggests that it is nether the temporal view of the resource (i.e. migrant vs. settled) nor the culture *per se* that affect resource use. Instead, it appears that the means of production and technologies associated with a cultural group affect patterns of resource use (in this case, gillnetting and wood dependent fish processing). It is interesting to note that while the Northern ethnic groups dominate the fishsmoking industry they introduced to the area, nearly one-third of fishsmoking stations are currently owned by people from other ethnic groups. This represents recent technology transfer and spread of an improved fishing technique within the villages.

This finding demonstrates the advantages and importance of using participatory approaches in conjunction with formal monitoring of resource use. The triangulation of methods enables the village construction of resource use to be tested and a rigorous model of patterns of resource use and their impacts to be defined.

Household fuelwood: patterns of collection and use

As is the case for rural areas in many developing countries, domestic fuelwood is a primary resource and the main source of household energy in LMNP. This section reviews domestic consumption of fuelwood and the role of women and their daughters in collecting this resource. The results presented are thought to provide some of the most detailed data to date on household fuelwood flows and the effect of family size on fuelwood use, demonstrating the economies of scale in fuelwood consumption. The data on patterns of wood collection support the frequent observations of the heavy work loads undertaken by rural women in the developing world (cf. Boserup 1989). They also indicate the significant contribution that female children make to the household through assisting in this task. Furthermore, the analysis suggests that nursing women maintain efficient patterns of fuelwood collection by integrating child care with their work activities (cf. Panter-Brick 1989).

- **Household size and fuelwood efficiency**

The results clearly show the economies of scale in fuelwood consumption. Two people use over 20 kg of wood each per week but *per capita* fuelwood consumption decreases rapidly with increasing household size, such that in a household with six people, each person consumes just over 10 kg of fuelwood per week. Hosier (1984) suggests that the economies of scale fuelwood use could be a factor contributing to high fertility and the maintenance of large households in developing countries. These results support his hypothesis that there is some fixed level of energy necessary to sustain a household under specific socio-economic conditions, such that each individual household member increases fuelwood consumption less than the previous member. This analysis suggests that the marginal cost of each household member up to about eight individuals is low and this appears to be the level at which households maximise fuelwood efficiency. Thus, the observed mean household size of six people in Chembe appears an efficient unit for fuelwood consumption. Other activities, such as water collection, are hypothesised to show a similar economy of scale.

- **Women, nursing and fuelwood collection**

The results suggest that women spend an average of over 380 hours *per annum* in fuelwood collection. This is higher than the estimated 300 hours *per annum* that Bryceson and Howe (1993) suggest Tanzanian women devote to wood collection. The present study indicates the equivalent of more than one hour of a woman's working day is occupied by fuelwood collection, which is just one of many household maintenance tasks.

Hurtado et al. (1992) note the trade-off between the time and energy women allocate to foraging tasks and to child care, yet the methods by which women accommodate children within their work schedules are poorly understood (Levine 1988). The present study suggests that nursing women are as efficient fuelwood collectors as non-nursing women, their load size and foraging times appear unaffected by the presence of a baby. These Malawian women, like the Tamang of rural Nepal (see Panter-Brick 1989), seem able to integrate child care into their work activities. The findings of these two studies contrast with those of hunter gatherer groups, where nursing women are often less efficient foragers (see Hurtado et al. 1985, 1992, Blurton Jones et al. 1989). Several factors appear important in the foraging decisions made by nursing women: the level of dependence on female labour, the age of the infant, perceived dangers in the environment and availability of alternative caretakers.

Fuelwood is a domestic requirement whose collection is undertaken exclusively by women. While their babies are small and need frequent feeding, nursing women have little option other than to have their babies accompany them on foraging trips. The additional weight of the baby does not appear to affect foraging patterns. However, women appear to carry their babies only when they are small and cannot be left for the approximately four hours duration of the trip. Older, heavier children would probably reduce foraging efficiency (cf. Blurton Jones et al. 1989) but as they also require less frequent feeding, they may be left with caretakers (e.g. grandmothers) in the village. Thus, by integrating baby care into the work place and utilising available childcare in the village, women in this society appear able to maintain efficient fuelwood collection in the absence of male provisioning and where there is total dependence on female labour for the collection of this resource.

- **Child labour, gender preference and theories of fertility**

Fuelwood collection within the protected areas appears to be one of the most energetically demanding household tasks for women living in the enclave villages (cf. Mehretu and Mutambirwa 1992). Women are assisted in this task by their female children. Using focal group follows of wood collection groups, the role and effects of children on domestic fuelwood collection and consumption were investigated and modelled using the regression curve for fuelwood consumption predicted from household size. The results are interpreted in terms of theories of fertility and the demand for children in developing countries. The labour of children within the household and the direction of inter-generational wealth flows are central to Caldwell's (1983) theory of fertility. He suggests that high fertility levels are economically rational for households in developing countries because the net wealth transfer from children to parents is positive. Although this has been difficult to measure empirically, preliminary studies suggest that child labour does not compensate for the cost of their cumulative consumption (Cain 1982, Kaplan 1994). This would suggest that the wealth flow from adults to children is positive, consistent with the predictions from evolutionary theory that the acquisition of wealth and resources should be in the service of reproduction, rather than *vice versa* (Kaplan 1994).

The present study suggests that a daughter repays her cumulative fuelwood costs and up to 2.25 of other siblings through her labour in fuelwood collection. However, the data suggest that the labour contribution a mother receives does not increase in proportion to the number of her daughters. Thus, while it is unlikely that decisions on family size would be based on fuelwood collection alone, these data do not support the theory that child labour is a driving force behind the high fertility in developing countries (cf. Kaplan 1994, see below). However, gender preference is also believed to sustain high fertility in developing countries. The present study supports the findings of Rahman and Da Vanzo (1993) who present demographic data from Bangladesh suggesting that parents, particularly mothers, desire at least one daughter. They attribute this to the greater contribution girls make to the household compared with boys, particularly in household maintenance tasks. From the present analysis it appears that it is also advantageous for women in this society to have at least one daughter because of the positive fuelwood contribution she makes to the household, reducing the maternal workload and repaying her cumulative fuelwood costs and those of two siblings.

Decision-making in fuelwood collection

Using methods adapted from behavioural ecology, particularly optimal foraging theory, the present study explores the decision-making that underpins fuelwood harvesting, in terms of the load size collected and the destination of wood collection groups. The latter is of particular relevance to resource collection within a protected area where penalties are imposed for illegal wood collection by MDNPW scouts. Earlier studies have shown the probability of detection is an important factor in determining the decision-making in whether to undertake an illegal activity (see Milner-Gulland and Leader-Williams 1992).

The present study applies a cost-benefit analysis to the collection of domestic fuelwood using time, energy, habitat and risk as factors with which to evaluate the women's decision-making. The results suggest that wood collection groups select areas within the National Park which minimise their expenditure of time and energy. This was hypothesised given the time women have to devote to wood collection and the demanding nature of wood collection given the steep topography of the Park. However, there is great variation in the length of journey made by wood collection groups. Contrary to expectation, longer journeys are not offset either by reduced patch times or enhanced loads. Thus women who make long journeys have both reduced rates of wood collection and energetic efficiencies.

The risk posed by law enforcement agencies and penalties for illegal wood collection appear not to affect female foraging decisions. At the current level of enforcement, women are unlikely to encounter patrols even in the highest risk areas or receive a penalty which would be a sufficient deterrent. The detection rate appears to be more of a deterrent than the penalty level in reducing the incentive for illegal activity (see Leader Williams and Milner-Gulland) but these results suggest that the detection rate is too low for patterns of wood collection to be influenced by law enforcement patrols.

Habitat appears to be an important factor influencing wood collection behaviour. Habitat is used as a proxy measure of wood quality, recognising that women show distinct preferences for fuelwood, in terms of species and size class. Women appear actively to select areas of mixed woodland and avoid closed canopy woodland for fuelwood collection. The energetic and time costs in accessing each habitat are thought to influence habitat preferences. Thus women appear to minimise the energetic and time expenditure per trip within the constraint that wood must be of a certain type or quality. This requires selection of appropriate areas of woodland around the village. Selection suggests that wood collection is likely to have an impact over a wide area of the resource base rather than being concentrated in woodland areas proximate to village. This pattern of utilisation is consistent with the changes in cover of sparse woodland detected by the aerial photographic analysis.

Final Conclusions: application and future directions for research

A major failing with development research is that it is not always accessible to those people who need the results (see Bradley 1991). Development planners require rapid turnaround between 'diagnosis and design'. By contrast, academic research is a lengthy process, utilising a critical and comparative approach to research design, implementation and analysis. An advantage to using both participatory and formal research techniques is that this approach can begin to reconcile rigour and rapidity and provide sufficiently precise information to be of both theoretical interest and applied worth.

Throughout this study, particularly in project planning, PRA was used to focus the research to reflect local needs and concerns (both those of MDNPW and the communities) within the current framework of conservation theory. However, patterns of resource use are dynamic and respond to the changing environment. Historical patterns of resource use and settlement (outlined in Chapters 4 and 6) demonstrate recent local change, which is likely to be a consistent feature of subsistence strategies. Thus, this thesis offers a status of knowledge report recognising that patterns of resource use will change in response to both extrinsic (e.g. policy change by MDNPW) and intrinsic factors (e.g. resource depletion). However, the continued use of consultative, participatory research should enable detection of change and the documentation of local current coping strategies. Moreover, the formal approaches and surveys (e.g. analysis of aerial photographs, vegetation survey and systematic household surveys) offer a reference point from which patterns of resource use and development initiatives can be monitored and evaluated.

The analyses presented address a range of conservation and development issues of both theoretical and practical application. Analysis of the patterns of resource use practised by different sectors of the community has been a recurrent theme throughout this thesis. While the household provides a convenient unit of study, particularly within a subsistence economy, the present study highlights the importance of a range of different factors that affect patterns of resource use. In particular age, gender, cultural group and wealth status are determinants of the access to and control over resources that influence patterns of woodland utilisation. Such parameters are important from both a theoretical standing in determining the sustainability of harvesting practices but are of practical value in community development projects based on the utilisation of natural resources.

The present study suggests that multi-disciplinary research, based on quantitative methodological approaches, provides a powerful tool for developing conservation theory and practice. An innovative approach has been the application of evolutionary ecology to the study of human resource use decisions. This allows a rigorous analysis of human behaviour and facilitates integrated ecological studies of human subsistence in the general context provided by current evolutionary and ecological theory. In the case of LMNP, this combination of methods has provided a local level approach to understanding the impact of different patterns of resource use. Furthermore, the study has demonstrated the importance of woodland products for both rural subsistence practices and economic activities.

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Appendices

Appendix 1

Wealth class criteria used during wealth ranking sessions: indicators of the standard of living experienced within each wealth class

Class 1

- House: large, often made of fired bricks, painted, may have iron sheets or a non leaking thatched roof. Cement floors, rim locks on plank wood doors. Glass louvre windows. Good, complete fence.
- Furniture: sofa, padded chairs, tables and metal beds.
- Vehicles: may have a pickup truck or bicycle. Many have plank boats and dugout canoes.
- Occupation: resthouse owners, fishermen entrepreneurs (owner of fishing gear and/or craft but may not actually be involved in fishing operation)
- Clothes: several sets of good clothes with no holes or patches. Leather shoes.
- Food: varied diet, eat chicken, rice and eggs regularly. Employ domestic help
- Schooling: all children go to school and many reach secondary education.

  Other: own radio cassette players and fishing nets ('chirimila')

Class 2

- House: good but small. May have fired bricks. Good thatch roof with no leaks. Rim locks on plank doors. Glass-paned windows and cement floor.
- Furniture: basic wooden chairs, a table and beds
- Vehicles: may own dugout canoes or bicycles.
- Occupation: either paid employment (in resthouses or for National Parks) or have own small enterprises such as beer brewing, fish trading, selling African cakes ('mandazi') or flour.
- Clothes: a couple of sets of decent clothes. Plastic or leather shoes.
- Food: eat rice or chicken occasionally. Afford cooking oil.
- Schooling: children attend primary school and some make MCDE, secondary

- Other: own radios and use a good brand of soap ('Geisha')

Class 3

- House: small and made of sundried bricks, thatched roof with some leaks. Bamboo doors and dirt floors. No glass windows.
- No furniture, may have small stools and mats.
- No vehicles
- Occupation: net crewers, women may sell fuelwood or grass for income, small businesses buying small amounts of tomatoes, peanuts or fish.
- Clothes: 'chitenjes' (piece of cloth) and one set of Western clothes, some patches and holes
- Food: monotonous diet of nsima and vegetable/fish relish. Limited amounts of cooking oil. Food available every day but some meals may be missed.
- Schooling: children tend to have primary education only.
- Other: use cheap brand of soap ('Maluwa') and have torn blankets. Use clay cooking pots

Class 4

- House: small, sundried bricks, leaking thatched roof, dirt floor, fence poor or absent. No sleeping quarters hence sleep within the fence or kitchen
- Furniture: mats only
- No vehicles
- Occupation: dependant on families and neighbours. Sale of fuelwood and grass (seasonal) are important income generating activities.
- Clothes: old chitenjes and patched clothes only
- Food: nsima and poor relishes only. Normally eat once a day, but experience hunger, some days there is no food.
- Schooling: children tend not to go to school because of the lack of money for uniforms and books.
- Other: often widows or unmarried/divorced women. Cannot afford to buy soap regularly, no blankets.

Appendix 2

Descriptions of the collection and use of NTFPs.

Primary Products

Domestic Firewood: This is collected predominantly by women. Dead wood and hardwood species which do not produce much smoke and burn for prolonged periods are preferred. Highly ranked species include: *Combretum* spp., *Brachystegia microphylla* and *Dalbergia nitidula*. However, women utilise a wide range of fuelwood species, a trade off between preferred hardwoods which are heavy to carry and lighter species which are less efficient fuelwoods. It should be noted that maize kernels were the only other source of fuel encountered during the period of study.

Firewood for fish processing: Fuelwood is used to smoke and preserve large, oily fish (for example, *Bathyclarias* spp. and *Bagrus meridionalis*), enabling its transportation to inland markets. Any non-latex and non-rubber hardwood tree species may be utilised as these do not produce smoke. Hardwood species similar to those selected for domestic fuelwood are preferred. Fuelwood of the large size required for fishsmoking is collected by men.

Building poles: Poles are required for constructing houses (house and roof supports) and building fences. Poles are collected on a needs basis by men. A wide range of tree species are utilised including planted exotics such as *Eucalyptus* spp. and bamboo. Indigenous preferred species include: *Lannea* spp., *Commiphora* spp. and *Sterculia africana*.

Grass: Grass is used to thatch houses and build fences. In season (April-July), bundles of grass are collected. Two major types of grass may be distinguished: that for general fencing and thatching ('udzu') and the favoured 'tsekela' (*Hyparrhenia* spp.) which provides a superior thatch. Grass is an important seasonal source of income, especially among the poorest sectors of the community.

Secondary Products

Wild plant foods: This category includes wild fruits, seeds, leaves and roots that are gathered from within the woodland or along the field/forest margins. Wild fruits are the most important wild plant food in the diet of Chembe village residents. Fruits are generally not included in meals, but are eaten between meals, as snacks, as they are encountered while walking in the woodland. Fruits from *Adansonia digitata*, *Flacourtia indica* and *Tamarindus indica* are especially favoured. Children make regular trips, in season, specifically to collect wild fruits while women collect fruit opportunistically, as they encounter them while wood collecting. Leaves, roots and seeds occur less often than wild fruits in the local diet. The leaves from annuals, such as *Amaranthus* spp. and *Ceratotheca sesamoides*, are collected from field margins for use in 'ndiwo' (relish) served with the local maize staple 'nsima'.

Medicines ('mankhwala'): A wide variety of plant species are used in traditional medicines although the scope of this research did not allow documentation of the many different plant remedies. For simple ailments, villagers may collect plants for self treatment. During prolonged illness and for more serious complaints, the traditional doctor ('sing'anga') may be consulted. Traditional birth attendants ('azamba') offer plant remedies for women, including contraceptives such as bark worn around the waist. Traditional practitioners charge for herbal cures.

Fibres and dyes: As a fishing village, tree fibres are important for rope making in Chembe. Fishing nets are generally purchased but ropes used for hauling in the nets may be made locally. The bark of the dominant canopy tree species, *Brachystegia microphylla,* is important in, and consistently ranked as the best tree for, rope construction. Ropes made from this bark last 3-4 months in a net being regularly used. Historically, beach seines and handlines were made from the bark of *Pouzolzia hypoleuca.* Nowadays, these fishing gears may be purchased although they are not frequently used, being superseded by more efficient gill and open water seine nets. Dyes are used to colour nets to make them invisible to fish. Dyes may be purchased but many fishermen use leaves from the tree *Elephantorrhiza goetzei* or the bark from *Sclerocarya caffra* as infusions to dye nets.

Bushmeat: Fish is the most important non-vegetable protein source, hence little of the diet comprises bushmeat. The most important species hunted by male villagers (both adults and children) include: rock hyrax (*Procavia capensis*), bush pig, (*Potamochoerus porcus*), klipspringer (*Oreotragus oreotragus*) and helmeted guineafowl (*Numida meleagris*).

Insects: In season, children collect various insects from the woodland and field margins. Flying termites, grasshoppers and sand crickets are gathered and used either as snacks or ndiwo.

Curios for tourist industry: Seeds are an important local resource because they are used to make curios for sale to tourists. Seeds are collected by boys, who also make jewellery to sell to Park visitors. Three local tree species are used to make jewellery: *Abrus precatorius*, *Jatropha curcas* and *Sterculia africana*. Seeds from the trees of *Afzelia quanzensis* and *Pseudolachnostylis maprouneifolia* are collected as counters for the local game 'bawo'. While only locally found within LMNP, wood from the Zebrawood (*Dalbergia melanoxylon*) is used for carving wooden pendants and other small curios for sale to tourists. Larger curios, such as chief chairs, are carved from wood obtained outside the Park, because the required large, hardwood species are not common within LMNP woodlands.

Domestic tools: Some utensils are made from local materials. However, many households purchase domestic utensils, either from markets in the nearby town of Monkey Bay or from local traders. Hoe handles and cooking utensils, such as stirring and nsima spoons, are made from a variety of hardwood tree species. Brooms are made from either a palm found at the southern end of LMNP and cultivated within farmplots, or from the woody shrub *Xerophyta spendens*, which is common within the woodlands. Mats, for sleeping and drying maize flour, are made by each household, by weaving palm leaves or reeds gathered along the lakeshore. Racks for drying fish and storing kitchen utensils are made from poles cut from the woodland.

Appendix 3

Species encountered during the vegetation survey and species codes used by the multivariate analyses

Species Code	Species Name
acanil	Acacia nilotica
adadig	Adansonia digitata
afzqua	Afzelia quanzensis
albant	Albizia antunesiana
albgla	Albizia glaberrima
albhar	Albizia harveyi
allafr	Allophylus africanus
antven	Antidesma venosum
azagar	Azanza garckeana
bautho	Bauhinia thonningii
bosang	Boscia angustifolia
brabus	Brachystegia bussei
bramic	Brachystegia microphylla
bricat	Bridelia cathartica
brimic	Bridelia micrantha
canfra	Canthium frangula
catspi	Catunaregum spinosa
comcae	Commiphora caerulea
comcol	Combretum collinum
comfra	Combretum fragrans
commar	Commiphora mariothii
commer	Commiphora merkeri
commol	Combretum molle
commos	Combretum mossambicense
comzey	Combretum zeyheri
crofeb	Crossopteryx febrifuga
crogra	Croton gratissimus
dalmel	Dalbergia melanoxylon
dalnit	Dalbergia nitidula
dalnya	Dalbergiella nyasae
diccin	Dichrostachys cinerea
diediv	Dielsiothamnus divaricatus
diokir	Diospyros kirkii
dioqui	Diospyros quiloensis
dipcon	Diplorhynchus condylocarpon
ehramo	Ehretia amoena
elegoe	Elephantorrhiza goetzei
eryaby	Erythrina abyssinica

Species Code	Species Name
eucnat	Euclea natalensis
euping	Euphorbia ingens
eupmat	Euphorbia matabalensis
ficabu	Ficus abutifolia
ficcap	Ficus capensis
ficnat	Ficus natalensis
flaind	Flacourtia indica
friobo	Friesodielsia obovata
garhui	Garcinia huillensis
grebic	Grewia bicolor
hapfol	Haplocoelum foliolosum
holpub	Holarrhena pubescens
hugbus	Hugonia busseana
hugori	Hugonia orientalis
landis	Lannea discolor
lansch	Lannea schimperi
lecfra	Lecaniodiscus fraxinifolius
lonbus	Lonchocarpus bussei
loncap	Lonchocarpus capassa
mardis	Margaritaria discoidea
marobt	Markhamia obtusifolia
milser	Millettia sericea
monbuc	Monanthotaxis buchananii
moneng	Monotes engleri
ochhol	Ochna holstii
ochrov	Ochna rovumensis
oladis	Olax dissitiflora
ormtri	Ormocarpum trichocarpum
ozoret	Ozoroa reticulata
pleafr	Pleurostylia africana
poldis	Polysphaeria dischistocalyx
pouhyp	Pouzolzia hypoleuca
psemap	Pseudolachnostylis maprouneifolia
psyliv	Psydrax livida
ptemyr	Pteleopsis myrtifolia
sclbir	Sclerocarya birrea subsp. caffra
steafr	Sterculia africana

Species Code	Species Name
steara	Steganotaenia aralicea
stekun	Stereospermum kunthianum
stequi	Sterculia quinqueloba
strispi	Strychnos spinosa
strmad	Strychnos madagascariensis
terser	Terminalia sericea
terste	Terminalia stenostachya
turrob	Turraea robusta

Species Code	Species Name
vaninf	Vangueria infausta
vanlan	Vangueriopsis lanciflora
vitdon	Vitex doniana
xerspe	Xerophyta spendens
xerstu	Xeroderris stuhlmannii
ximcaf	Ximenia caffra
zanafr	Zanha africana

Appendix 4

Two-way table produced by TWINSPAN

Scores in the table reflect the abundance of each species in each quadrat.

	Group Number	A	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	D						
	Quadrat	1	1	2	2	4	0	0	1	3	4	4	0	0	0	2	2	2	2	2	3	0	1	1	4	1	3	3	3	3	4	1	1	0	1	2	2	3	0	0	1	2	3	3	4	4	3	4	4						
	Number	6	1	1	3	4	5	6	5	5	6	7	2	7	8	2	5	6	7	9	6	9	3	4	8	0	1	2	3	7	1	2	9	1	8	0	8	4	3	4	7	4	9	0	3	5	8	0	2						
Class No.	Species																																																						
5b	acanil						1																																											0	0	0	0	0	0
5b	commer																			2																														0	0	0	0	0	0
5b	eupmat													4							1																													0	0	0	0	0	0
5b	ochrov															2	2																																	0	0	0	0	0	0
5b	oladis										1			2	2																																			0	0	0	0	0	0
5b	commol																					1																												0	0	0	0	0	1
5b	crogra																							2																										0	0	0	0	0	1
5b	eucnat																				2	2	1			1																								0	0	0	0	0	1
5b	garhui																						1																											0	0	0	0	0	1
5b	hapfol		1												1								2	1																										0	0	0	0	0	1
5b	hugori														2								1	2																										0	0	0	0	0	1
5b	milser																						3																											0	0	0	0	0	1
5b	monbuc		1																			3	2	2																										0	0	0	0	0	1
5b	ochhol																						1	1																										0	0	0	0	0	1
5a	adadig	1																																																0	0	0	0	1	0
5a	albgla	2																																																0	0	0	0	1	0
5a	bosang	3		1		1													1	1			2																											0	0	0	0	1	0
5a	brabus	5																																																0	0	0	0	1	0
5a	canfra	3																																																0	0	0	0	1	0
5a	commar	1																																																0	0	0	0	1	0
5a	euping	2																																																0	0	0	0	1	0
5a	ficabu	1																																																0	0	0	0	1	0
5a	pouhyp	1																																																0	0	0	0	1	0
5a	*turrob*	3																																																0	0	0	0	1	0
5a	comcae	2															1																																	0	0	0	0	1	1
5a	dioqui	3				1											3				2														1															0	0	0	0	1	1
5a	mardis	2												3	1																					1														0	0	0	0	1	1
5a	marobt	4												3	1	1				1																								1						0	0	0	0	1	1
4	bramic	2		2	1	2	3	3	4	3	3	3	2	4	4	4	2	2	3	2	3	4	4	4		2	1				2			1		2					3			2	1	2				0	0	0	1	0	0
4	dalnit		1		3		2	3	3		3	1		1	3		2	2	2	2	1	1	3	2		1	2					2		1	2				4	3	2									0	0	0	1	0	0
4	psyliv	3			1	1							2	4	3	3	3	3	3	3			1	4													2		1					2	1	2				0	0	0	1	0	0
4	strmad										1			2	2	4	2			2	1				1									2												2				0	0	0	1	0	0
4	brimic	2		3	2		2	1		2						1					1								2	1																				0	0	0	1	0	1
4	diediv																															1																		0	0	0	1	0	1
4	vitdon				1				2				1				1					1		2			1		1		1	1													1					0	0	0	1	0	1
4	commos						1	2						1												2								1																0	0	0	1	1	0
4	lansch	2					3	1				1		1	1	4					2					2	1	1		1	1		1	2				2	2								1			0	0	0	1	1	0
4	lecfra	1		2	3		1																		1				1		1	1		2																0	0	0	1	1	0
4	diccin							3	2				1																					1	1			3			1									0	0	0	1	1	1
4	ficcap																1																											1						0	0	0	1	1	1
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1						
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1							
		0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1							
			0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1							
							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	0	1	1	1									
							0	0	0	0	0	0	1	1	1	1	1	1	1	1	1					0	0	0	0	0	0	1	1		0	0	0	0	1	1	1														

Appendix 4 continued.

	Group Number	A	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	D						
	Quadrat	1	1	2	2	4	0	0	1	3	4	4	0	0	0	2	2	2	2	2	3	0	1	1	4	1	3	3	3	3	4	1	1	0	1	2	2	3	0	0	1	2	3	3	4	4	3	4	4						
	Number	6	1	1	3	4	5	6	5	5	6	7	2	7	8	2	5	6	7	9	6	9	3	4	8	0	1	2	3	7	1	2	9	1	8	0	8	4	3	4	7	4	9	0	3	5	8	0	2						
Class No.	Species																																																						
3	allafr			1	2	2	2	1	1	1	2	2			1	1							1	1	2	2	2	2	2		3	3		2	1	1		1			1			1						0	0	1	0	0	0
3	antven																1								2							2										1								0	0	1	0	0	0
3	dalnya				1									2	1			2	3		2											2		1		2	2	3				2	2	2	2	2				0	0	1	0	0	0
3	dipcon			1		3	4	4	3	2	3	4	2	2	3	2	4	3	4	4	2		2	2	2	4	5	2	3	2	2		3	4	1	4	2	4	5	4	3	4	3	3	3		2	3		0	0	1	0	0	0
3	ficnat						1																									2																		0	0	1	0	0	0
3	hugbus						1																													1			2											0	0	1	0	0	0
3	landis			3	1	2						1	1			2				3										1		1		2		1					2	2		3	2	2				0	0	1	0	0	0
3	psemap					1	3	2	2	2	2	2		1	2	1	2	1	2	2	1				2	1	2	3	1	3	1	2		3		2	2	1	3	2		2	1							0	0	1	0	0	0
3	ptemyr	1																			1										2																			0	0	1	0	0	0
3	steafr	2																							1									1																0	0	1	0	0	0
3	xerstu	3				1	3			1																1	2		2		1	2	1	2	2					1		1	1							0	0	1	0	0	0
3	eryaby																	2									1									1								3						0	0	1	0	0	1
3	grebic	2					1																								1	1												1						0	0	1	0	0	1
3	terste						1	2									2											2	2		1	1	1					4					2	1	1	1		2		0	0	1	0	0	1
3	flaind	2			1											1		2	1						2						2		1	3				1	2		2						1			0	0	1	0	1	0
3	steara	2														1																		1		2		1												0	0	1	0	1	0
3	zanafr	2				1														1					2									3				4												0	0	1	0	1	0
3	diokir				1							2	1					2	1	1														2	1	2	3	1	2	2			1			1				0	0	1	0	1	1
3	ozoret							1				1									2														1		1	1	2		2									0	0	1	0	1	1
3	afzqua																																2										1							0	0	1	1	0	0
3	catspi						1								1																	1	2	5							1					2	1			0	0	1	1	0	0
3	comcol																			2	1						2	2			1	2																		0	0	1	1	0	0
3	comzey					1																				1					3		2	4														1		0	0	1	1	0	0
3	stekun			2	2	1												2		2	1				4		2			1	2	1			2	1	3	2		1							1	3		0	0	1	1	0	0
3	vaninf											1											2			1	1		2		2	2		1	1	1		1							1	1				0	0	1	1	0	0
3	azagar																																														1			0	0	1	1	0	1
3	elegoe																																								1							3		0	0	1	1	0	1
3	lonbus					1																						1			1							1				2			2	2	2	1		0	0	1	1	0	1
3	stequi																																															1		0	0	1	1	0	1
3	xerspe																																											1						0	0	1	1	0	1
3	bricat									1							1								2		3				2		2	3	1	2	1	2	2		2		1	1	1	2				0	0	1	1	1	0
3	holpub																								3		1						1	5													3			0	0	1	1	1	0
3	pleafr																																	1	1					1						1				0	0	1	1	1	0
3	vanlan																																			1								1						0	0	1	1	1	0
3	albant																																								1									0	0	1	1	1	1
3	bautho																				1														1		1	2			1									0	0	1	1	1	1
3	crofeb																													1		2	1	2	1	1	2	2		3	1		1							0	0	1	1	1	1
3	dalmel																																			1		1												0	0	1	1	1	1
3	ehramo																																	4																0	0	1	1	1	1
3	friobo																																	1																0	0	1	1	1	1
3	moneng																										1																							0	0	1	1	1	1
3	ormtri																																	1					1	1										0	0	1	1	1	1
3	poldis																									1																								0	0	1	1	1	1
3	strspi																																2		1		1		1		1									0	0	1	1	1	1
3	terser																																1	2	1			1												0	0	1	1	1	1
3	ximcaf																																	1																0	0	1	1	1	1
2	comfra					4	4	2	2	2			1	2	3	2	3	2	2	2	1		1	1			2	2	2	2	2	4	4	5		2	2	3	3	2	2	3	3	3	4	3	5	4	1	0	1				
2	loncap																				1											2	2	2							2								1	0	1				
2	sclbir																																1	2								5					1		2	0	1				
1	albhar																																																4	1					
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1						
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1							
		0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1							
			0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1							
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							0	0	0	0	0	0	1	1	1	1	1	1	1	1	1					0	0	0	0	0	0	1	1		0	0	0	0	1	1	1														

Appendix 5

Village Population Data [a]

Year	Chembe		Msaka		Mvunguti		Zambo	
	Pop. [b]	Rate [c]	Pop.	Rate	Pop.	Rate	Pop.	Rate
1966 [1]	1865	1.9	/	/	/	/	/	/
1977 [1]	2055	0.9	1546	/	661	/	353	/
1987 [1]	3125	4.2	2441	4.6	1622	9.0	414	1.6
1992 [2]	4670	8.4	2534	0.7	/	/	420	0.3
1994 [2]	3252		2495		2106		464	

[a] Village data unavailable for Chidzale, except for the two independent censuses:
1992 175 residents
1994 123 residents
[b] Pop.: number of permanent residents
[c] Rate %: Intercensal exponential growth rate (Kpedekpo 1982)
/ Data unavailable

Source of data:

[1] National Census
[2] Independent Surveys, 1992 (WWF), 1994 (Author). These surveys employed the same executant, who also undertook the 1987 National Census among the enclave villages. Hence, the intercensal growth rates combining the two data sets are likely to estimate real rates of population growth and not be an artefact of different types of survey.

Appendix 6

Household Survey Questionnaire

Initial Interview

Family Name ____________________ Household Number ____

Number living in house __________

	Name	Year of birth	Education level
Mother	___________	____________	______________
Father	___________	____________	______________
Child 1	__________	____________	______________
Child 2	__________	____________	______________
Child 3	__________	____________	______________
Child 4	__________	____________	______________
Child 5	__________	____________	______________
Child 6	__________	____________	______________
Other	____________	____________	______________
Other	____________	____________	______________

Follow-up Interview I: Economic activities

Occupation of head of household __________________________
(major economic activity)
Other income generating activities _________________________________
Woman IGA ____

Landholding Size (hectares) ___________________

Follow-up Interview II: Tree Crops and their Uses
List all trees/shrubs grown within the household, together with their uses

List all trees/shrubs grown within farmplot, together with their uses

Appendix 7

Size Classes of Woody Resources

Size classes were arbitrarily determined in 5 cm increments of the measured mid-point diameter of selected woody resources used within the villages. Thus:

Size Class	Midpoint diameter/cm
1	<5
2	$\geq 5 - <10$
3	$\geq 10 - <15$
4	$\geq 15 - <20$
5	$\geq 20 - <25$

Appendix 8

Income and the opportunity cost of labour

Women wood sellers

- Frequency of wood collection.
  By tracking women who sell fuelwood regularly, estimate frequency of fuelwood collection trips (see Chapters 8 and 9)
  2 trips per week (intercollection interval is 3.8 days)
- Average collection time
  By tracking women wood collectors, the average time for a wood collection trip is calculated
  5 hours (average trip lasts 294 minutes)
- Price of firewood bundle
  Wood is sold either to rich households or to tourist facilities (resthouses and restaurants) in the village
  Price MK 5 per bundle

Opportunity cost of women's labour:

10 hours work per week earning MK10,
6 working days per week (Mon-Sat, no labour is undertaken on Sundays)
= 1.67 hours work per day @ MK1 per hour
= MK 1.67 per day opportunity cost of women's labour

Male Net Crewers

Men do not collect any of the NTFPs that are currently marketed within LMNP villages. Fishing is the major economic activity within the enclave villages. Net crewers are employees of the owners of the fishing gear. They operate or assist in operating the gear. This is the major source of employment within the artisanal fishery. Fish catches are seasonal and opportunistic, crewers are paid according to the number of 'tins' of fish harvested. The following data is taken from a year-long study on the Chembe fishery (Smith 1993a).

- Average number of trips
  144 trips per year, 12 trips per month
- Average number of tins caught (across all seasons)
  68.02 tins per year, 5.67 tins per trip
- Average monthly income for each net crewer,
  12 trips @ 5.57 tins per trip @ MK 3 per tin
  = MK 204.12 average income per month
- Average number of working days per month
  6 working days per week, no fishing on Sundays
  26 working days
  MK 204.12/26 = MK 7.85 per day opportunity cost of men's labour

Appendix 9

Opportunity Cost of Capital

There are few people who lend capital in Chembe village. Those that do are: salaried employees (for example, working for the Malawi Department of National Parks and Wildlife), fishermen and those involved in tourist related activities. Criteria for lending: relatives, friends or those who are acquainted to them in some way i.e. those people whose credit record is known or can be vouched for conferring low risk lending.

Interest Rate: 50 per cent per month

Opportunity Cost of Capital: 600 per cent *per annum*

Appendix 10

Wood collection tracking

Date: _________ Day: _______________

Time leave village: ____________

Time start searching for firewood: ______________

Distance walked to the wood: __________ Climbing: ________

Time put wood on head: ____________

Time arrive back in village: ___________

Distance walked back to the village: _________

Name place wood collected: _______________ Grid Square: ___

Number women with tickets: _____

Number women without tickets: _____

Encounter scout Yes/No, if Yes, record square number and what action taken:
____

Name of Woman	Weight of woman	Name and weight of daughter	Time start to tie bundle	Weight of woman with wood	Weight of daughter with wood	Day last collecte d wood

Appendix 11

Woodland Patrol Report

Personnel:______________________________________
General area patrolled:______________________________
Square numbers:______________________
Date(s):______________ Time out:_______ Time in:_______
Distance patrolled:______________ miles/kms
Total number of groups encountered collecting firewood or cutting trees:______________

<u>DETAILS OF ENCOUNTERS WITH PEOPLE COLLECTING FIREWOOD OR CUTTING TREES</u>

Please fill in the table for EACH of the groups encountered.

DATE	No. OF PEOPLE IN EACH GROUP	SQUARE No. WHERE GROUP FOUND	VILLAGE BASE OF GROUP	No. PEOPLE WITH TICKETS	No. PEOPLE WITHOUT TICKETS	REASON FOR NOT HAVING A TICKET	ACTION TAKEN WITH EACH GROUP

Appendix 12

Energetic Costs of Load Collection for each grid square.

The formula used to estimate E, the energetic expenditure in return travel to each grid square is:

$$E = \underbrace{\sum_{i=1}^{n} (t_i k_i) f_i}_{\text{Energy Outward}} + \underbrace{\sum_{i=1}^{n} (t_i((w_i l_i) + l_i)) f_i}_{\text{Energy Return}}$$

where k is the caloric cost of walking each kilometre to the resource base
l is the caloric cost of walking each kilometre back to the village
t is the terrain co-efficient
w is the % increase in caloric expenditure due to the excess weight of load.
The summation sign allows for variability in costs per unit of distance for gradient and terrain, while f denotes the number of kilometres the costs remain constant.

Key:

- Terrain Co-efficients, Dirt Road = 1.1, Light Brush 1.2 (Soule and Goldman 1972)
- Estimated increase in caloric cost (per cent) with 27.25 kg increase in weight at all negative gradients and on level ground = .218 (McDonald 1961)
- Energy Cost of walking on level ground = 50.6 Cal/Km
- E uphill, energy expended in walking uphill at given gradient
- E downhill, energy expended in walking downhill at given gradient (see McDonald 1961).

Gridsquare Number	Distance (level) km	Distance (uphill) km	Gradient	E uphill Cal/km	E downhill Cal/km	E Cal
A1	4	0.8	14.7	140.2	39.6	674.7
A2	5.1	1.9	12.2	115.2	36.6	993.9
B1	1.4	1.5	18.1	169.4	60	609.3
B2	1.7	3.3	18.9	169.4	60	1170.1
B3	2.6	0.9	6.1	75.4	39.8	454.8
B4	3.2	2	24.4	202.8	69.2	1084.1
C1	5.1	3.3	16.7	140.2	39.6	1375.9
C2	5.2	3.3	22.2	169.4	60	1602.2
C3	3.2	3.9	20	169.4	60	1529.9
D1	4.7	1	8.9	115.2	36.6	772.0
D2	5.6	1.4	13.3	140.2	39.6	1008.0
D3	5.7	2.6	20	169.4	60	1460.2
D4	6	2.6	12.2	115.2	36.6	1239.2
H1	3.2	2.3	15.6	140.2	39.6	915.2
H2	3.2	3.1	20	169.4	60	1297.1
H3	3.1	0.7	22.2	169.4	60	586.4

Gridsquare Number	Distance (level) km	Distance (uphill) km	Gradient	E uphill Cal/km	E downhill Cal/km	E Cal
H4	3.2	2.4	20	169.4	60	1093.4
H5	4.3	0.8	14.4	140.2	39.6	711.7
H6	3.1	2.3	10	115.2	36.6	823.7
H7	3.3	0.7	8.9	115.2	36.6	541.6
I1	3.7	3.3	20	169.4	60	1417.0
I2	4.7	2	22.2	169.4	60	1162.2
I3	4.8	3.9	24.4	202.8	69.2	1936.1
J1	5.9	0.9	21.1	169.4	60	990.3
J2	5.7	3	23.3	202.8	69.2	1737.2
J3	5.5	0.7	10	115.2	36.6	813.2
J4	5.9	1.5	16.7	140.2	39.6	1067.6
J5	5.9	3.3	11.1	115.2	36.6	1361.1
N2	8.3	0.9	11.1	115.2	36.6	1197.2
N3	8.9	2.4	15.6	140.2	39.6	1641.4
N4	9.8	0.4	7.8	115.2	36.6	1286.5
N5	9.8	2.3	8.9	115.2	36.6	1650.9

For example, energy cost of wood collection in Grid Square A1:

- Energy expended on outward journey:

((1.1 x 50.6) x 4.0) + ((1.2 x 140.2) x 0.8) = 357.23

- Energy expended on return journey loaded:

((1.2 x ((.218 x 39.6) + 39.6)) x 0.8)+((1.1((.218 x 50.6) + 50.6)) x 4.0) = 317.48

- Total energy expended = 674.7 Cal

Appendix 13

Energetic costs of load collection for each group of tracked wood collectors

Key

Variables and equation as per Appendix 12.

% Energy loaded: estimated increase in caloric cost (per cent) with bundle of known weight at all negative gradients and on level ground (see McDonald 1961).

Group Number	Distance (level) km	Distance (uphill) km	Gradient	Bundle weight (kg)	% Energy loaded	E uphill Cal/km	E downhill Cal/km	E Cal
1	0.384	0.128	18.1	32.8	0.2624	169.4	39.6	80.8
2	0.816	0.192	6.1	28.57	0.22856	75.4	39.6	129.2
3	1.056	1.248	24.4	36.02	0.28816	202.8	69.2	560.3
7	0.448	0.144	18.1	26.46	0.21168	169.4	60	97.2
8	0.544	0.176	18.1	27.03	0.21624	169.4	60	118.4
9	0.608	0.224	18.1	28.38	0.22704	169.4	60	140.2
10	1.168	1.872	18.9	21.47	0.17176	169.4	60	688.9
11	1.072	2.064	24.4	27.58	0.22064	202.8	69.2	843.4
12	1.552	1.328	24.4	31.17	0.24936	202.8	69.2	649.1
13	1.872	0.736	22.2	33.35	0.2668	169.4	60	445.3
14	2.096	0.448	21.1	30.65	0.2452	169.4	60	389.1
15	1.744	0.688	8.9	22.8	0.1824	115.2	39.6	350.2
16	2.176	0.368	8.9	27.28	0.21824	115.2	39.6	340.8
17	2.832	0.464	11.1	24.85	0.1988	115.2	39.6	440.6
18	3.536	0.448	12.2	26.21	0.20968	115.2	39.6	524.4
19	1.088	0.416	24.4	20.45	0.1636	202.8	69.2	277.6
20	1.248	0.336	22.2	30.73	0.24584	169.4	60	251.8
21	1.104	0.304	21.1	25.84	0.20672	169.4	60	224.7
22	0.192	0.768	22.2	36.7	0.2936	169.4	60	247.2
23	0.288	0.704	14.4	27.03	0.21624	140.2	39.6	194.7
24	0.224	0.432	22.2	23.03	0.18424	169.4	60	153.4
25	2.384	0.304	8.9	17.57	0.14056	115.2	39.6	353.9
26	0.448	0.144	18.1	13.06	0.10448	169.4	60	97.2
27	1.168	0.176	14.7	15.93	0.12744	140.2	39.6	184.0
28	1.57	0.528	18.9	20.9	0.1672	169.4	60	347.5
29	0.624	0.112	6.1	20.83	0.16664	75.4	39.6	93.7
30	0.928	0.16	6.1	30.52	0.24416	75.4	39.6	138.3
31	0.752	0.208	14.4	18.78	0.15024	140.2	39.6	139.9
32	0.944	0.496	22.2	24.77	0.19816	169.4	60	260.9
33	0.256	0.464	14.4	26.05	0.2084	140.2	39.6	136.5
40	0.592	0.144	18.1	19	0.152	169.4	60	115.0
41	1.312	0.176	18.1	23.45	0.1876	169.4	39.6	207.9
45	0.336	0.064	6.1	17.2	0.1376	75.4	39.6	51.0

Appendix 14

Application of this Study for the Integrated Management of LMNP

The aerial photographic analysis suggests there is an urgent need to provide alternative sources of woody biomass for the enclave villages. Monitoring of the harvesting of woody resources suggest that building poles and fuelwood (for use both domestically and for fishsmoking) are important woodland resources. By identifying selection preferences for these products, this study can be used to find solutions to the high levels of harvesting by the enclave villagers and provide a basis for the informed management of LMNP. Given the patterns of use and collection of fuelwood for fishsmoking and domestic purposes differ, strategies for woodland conservation should be similarly diverse.

Fishsmoking appears to be a major and recent cause of woodland decline. Open wire fishsmoking places have a high fuelwood consumption: trials around Lakes Chilwa and Chiuta, Malawi, suggest approximately 1 kg of wood is required to smoke 1 kg of fish (Walter 1988, Wilson 1992). Wood demand for fishsmoking may be reduced through use of more fuel-efficient (improved) smoking kilns. Fish smoking studies on the Zambian shore of Lake Kariba (Scholz 1993), indicate that 6 - 10 times less fuelwood is used in improved kilns compared to traditional open-wire smoking places. Introduction of such technologies would require active participation in the villages, by both the MDNPW and the Department of Fisheries, to encourage local people to take responsibility for their own resources. Such community extension efforts should be sensitive to the different cultures involved in fish processing.

The flexibility in species used for domestic fuelwood and building materials, facilitates the planting of a range of multi-use tree species to meet local needs. The present study supports the findings of other researchers (see Bradley 1991 and Dewees 1995) indicating that some of the requirements for woody products, especially building poles and domestic fuelwood, can be met through the maintenance and cultivation of trees in farm and household plots. These trees reduce woodland dependence and indicate that communities can enhance their environment through their subsistence practices (cf.

Fairhead and Leach 1995a, 1995b). The importance of such resources tends to have been ignored by conventional forestry approaches to the 'woodfuel' crisis (cf. Bradley 1991, Mearns 1995).

The present study also indicates that the household plot itself is used extensively for planting trees. Villagers asserted that they could take better care of trees when they were proximate to the household and, hence, close to the lake. While the survey of trees planted suggests that few trees are planted or maintained in farm or household plots specifically for use as domestic fuelwood, villagers claim to use the brush and deadwood from any trees (whether planted for poles, medicine or fruits) as firewood. Indeed, wood from various domestic trees (e.g. mango, *Mangifera indica*) was encountered during household surveys. This corroborates the findings of rural development forestry (see Shepherd 1993) that people prefer to plant trees for purposes other than fuelwood.

During my research in Malawi, I participated in a Concern Universal household food security project which sold fruit trees in the enclave villages of LMNP. The uptake and overall survivorship of trees from this project, despite it being a drought year, suggest that people are prepared to invest their time and energy in caring for economically important trees. The fruits from these trees were eaten by the household but could also be used for income generation. Monitoring the local market in Chembe demonstrated that fruits (especially mango and papaya) were frequently for sale as the turnover in the tourist industry provided a continuous (albeit seasonal) market for locally grown produce. This appears to be best point of sale for villagers despite the apparent higher prices received in urban areas.

Because of the high population density of the enclaves, land is at a premium and thus spare land for woodlots or buffer zones may not be available. Promoting tree planting within farm and household plots is one method of reducing dependence on the *miombo* woodland that does not require additional land. Furthermore, the availability of fuelwood as a by product of trees grown in farm and household plots would reduce the energetic and time burden of fuelwood collection on women and their daughters.

While it is unlikely that the total village demand for fuelwood could be met through tree planting, if combined with other strategies, such as community fishsmoking kilns, the problem of woodland decline could begin to be addressed.

The present study has highlighted the need for greater consultation between the MDNPW and the enclave villages. An area of particular importance is the requirement for an early burning regime within the Park, developed in a way to enable villagers to collect grass thatch and to promote regeneration of *miombo* species which tend to be superseded by *chipya* species under the current *ad hoc* burning regime. *Chipya* species provide a patchy canopy which may not adequately protect hillslopes. Maintenance of closed canopy *miombo* is particularly important on steep slopes to fulfil the Park's objectives to protect watersheds from erosion. A rotational early burning strategy should be developed to maintain *miombo* species which are the preferred local fuelwoods and yet are uncommon at accessible sites under the current *ad hoc* fire regime. To enable communities to collect grass thatch for their construction needs, later burns in other areas will promote *chipya* species. Details of the rotational burning to promote the regeneration of *miombo* species should be designed by Park staff in conjunction with the villagers.

The risk posed by law enforcement patrols (in terms of the encounter rate and penalties imposed) has implications for the community participation *versus* preservationist approaches to conservation (IIED 1994). At its current level the effective patrol rate (Bell 1984) appears too low to affect female foraging decisions yet law enforcement is a major point of contention between villagers and the MDNPW. While more resources could be targeted towards patrols to make them more effective, law enforcement fails to address the cause of the conflict: the Park woodlands are the only source of fuelwood for the enclave villages. Thus, a more proactive role for scouts in providing alternative sources of fuelwood (through tree planting, tree nurseries) may have a more beneficial impact on the woodlands than increasing law enforcement effort.

Furthermore, during the period monitored less than 5 per cent of scout encounters with illegal wood collectors were with male wood collectors. The analysis presented in this thesis suggests that the collection of fuelwood for fishsmoking appears to have a more damaging impact on the *miombo* woodland than domestic fuelwood collectors. Thus, the targeting of patrols to detect and deter the tree felling associated with wood collection for fish smoking may provide a better use of scout resources.

In summary, the present study indicates the importance of woodland products to the enclave villages of LMNP. However, the harvesting of these resources has a substantial impact on the woodland vegetation. Future management of LMNP should aim to reconcile the local needs for NTFPs and the conservation of the *miombo* woodlands with an appropriate integrated management plan. This should be developed in conjunction with the local communities to enable those who bear the costs of the protected area (through restrictions on access to resources) to also partake of its benefits (through development initiatives implemented by the MDNPW e.g tree nurseries and opportunities for income generation through National Parks tourism).